CRANFIELD UNIVERSITY

NAYEF S. AL-BDOUR

INTEGRATED PRODUCT DEVELOPMENT METHODOLOGY USING DUAL MODE QFD AND FUNCTIONAL HIERARCHY APPLIED TO A REAL CASE IMPLEMENTATION

CENTRE FOR DEFENCE ENGINEERING
MSc. by Research

THIS THESIS IS SUBMITTED IN FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MSc
Academic Year: 2013 - 2014

Supervisors: Professor Amer Hameed
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ABSTRACT

Technological developments are extremely fast paced in the modern world. However, application of new approaches in production of products has to be balanced against economic constraints. Consequently, with the development of new technologies and while striving for effective, efficient and low cost products, new and complex product development methodologies have evolved to develop a concept.

Getting to know customer needs and their priorities to establish a new concept is critical in the development process. The research outlined herein utilises the established methodologies of the Kano, Analytic Hierarchy Process (AHP), and Quality Function Deployment (QFD) techniques to identify top-level core user requirements and the technologies that can lead to effective and competitive product development.

Application of the above tools has allowed the development of an “Integrated Dual Mode QFD” analysis that offers a more holistic coverage of the customer needs spectrum compared with the traditional QFD, this is done by associating the priorities and competitiveness of individual needs through both of AHP and Kano methods. This approach avoids inconsistencies in customer needs and priorities.

Systems specifications obtained from the QFD analysis were used to undertake development of a functional model. This activity links the ‘Whys’ with ‘Hows’ that lead to the development of a system architectural model.

Using the above tools, a modular architecture concept has been developed for a Militarised All-Terrain Vehicle (MATV). The architecture offers future variants with improved performance in terms of power, agility, dash speed, reduced weight, mobility based survivability and network-centric communication for better situational awareness.

Overall this methodology allows a comprehensive systematic approach to concept development resulting in shorter system design and development time, while ensuring all aspects of customer voices have been taken into account to avoid costly integration issues later in the validation and verification stage.

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MATV	Militarised All-Terrain Vehicle
AHP	Analytic Hierarchy Process
CS	Customer Satisfaction
CR	Customer Requirement
FR	Functional Requirement
EV	Eigen Vector
GWP	Global Weighted Priority
QFD	Quality Deployment Function
CN	Customer Need
VOC	Voice of Customer
OAP	Open-Architecture Product
FR	Functional Requirement
NFR	Non-Functional Requirement
QA	Quality Attribute
IM	Interface Matrix
P	Physical
I	Information
M	Material
E	Energy
JISM	Jordan Institution for Standards and Metrology
OAP	Open-Architecture Product

1 INTRODUCTION

Product competitiveness has become one of the main concerns that affect products development processes over the last few years. Some of the main drivers for such concerns are competition, global macro-economic conditions, the issue of return on research development and, most importantly, appreciation of stakeholder requirements.

Return on research and development is difficult to achieve in real-time due to the long lengths of time that need to be allocated, and the effect of financial depreciation. Consequently, there is a need to develop a product which, while innovative, is developed with cost effective investment keeping on board all stakeholders.

Furthermore, the use of product development methodologies – such as the Stage-Gate process (Otto and Wood, 2001) – to achieve competitive products is rapidly gaining acceptance within a large number of industries, such as the automotive, and military industries. Despite this, most of these industries are struggling to find a suitable approach to allow them to develop the right combination of these methodologies to suit their unique needs.

In the automotive industry, where complex products need to be competitive in more than one aspect, a well-tailored product methodology is particularly important. In this regard, in this thesis a well-balanced methodology has been established and implemented on a case study vehicle. The research exploits one of The King Abdullah II Design and Development Bureau (KADDB) current land vehicles projects as a case study. The project in question is known as KADDB's Militarised All-Terrain Vehicle (MATV); furthermore, the research presented here aims to lay the ground for the KADDB's upcoming second generation MATV.

1.1 Objectives

(1) To propose a suite of integrated product development methodologies for correlating customer needs with key product characteristics to allow development of a multipurpose and competitive all-terrain military vehicle.

(2) To ensure realistic assumptions and practical solutions are achieved via the implemented methodologies by drawing comparison to a realistic case study.

1.2 Problem Statement

A product which does not meet a customer’s expectations, results in poor satisfaction, lack of customer delight, a loss of market share and investment. Engineers through the years of research have developed a number of tools which aim to assist one in developing the concept methodology in a systematic manner, taking into account holistic approach to ensure the customer’s views are taken into consideration. However, almost all these methodologies are generalised and require some level of customisation to suit the problem needs.

Understanding the customer needs is a foundation stone in the development of any product. If the foundation is poor it will result in a building which will collapse in time. Thus understanding the customer needs and the level of satisfaction or dissatisfaction is vital to the success of any project

The most of, these methodologies don’t fully explain how to capture and segregate between different types of customer requirements including the attractive and basic requirements. Therefore one of the aims of this study is to identify suitable tools which can be customised to specially address the development and product enhancement of a system which is to be self-sustained, highly reliable, efficient in its performance, and work in different types of challenging scenarios.

Based on this there was a motivation to develop a methodology by improving upon the stage gate process and the introduction of techniques for capturing the basic, one-dimensional and attractive customer requirements

Therefore, the subsequent aim is to identify and utilise product design methodologies that could assist in the improvement of the customer needs capturing tools, segregating the customer needs into various categories and correlating those needs to the performance parameters.

The functional and product architecture analysis were also undertaken to link ‘why’ and ‘how’ to ensure product meets customer needs and generates satisfaction. In addition, functional modelling helped to ascertain that the specifications derived in QFD analysis are achievable.

The research outlined here was conceived to utilise and integrate a carefully selected product development design workflow to develop an innovative and competitive MATV. The research has been designed to follow the Stage-Gate development process (Waterfall) (Otto and Wood, 2001).

1.3 Background and Significance

The 1st generation MATV was developed with the collaborative efforts of all KADDB’s managerial and technical resources. The newly developed vehicle has gone through all the traditional sequential phases (Takeuchi and Nonaka, 1986) of new product development processes, including: pre-concept; concept; design; demonstration; production, and; launch (Fox, 1993). Although the vehicle managed to achieve the set goals for the project, but there was still an aspiration to achieve a higher levels of customer satisfaction.

This requirement has necessitated the utilisation of advanced and more efficient methodologies in the early stages of the product development process with greater emphasis on customer requirements in order to improve the customer satisfaction levels and thus enhance confidence and sales figures for the 2nd generation MATV.

Out of many tools, a set of methods were selected such as Kano model with its enhanced capability in segregating the requirements and clarifying customer response to its implementation, the AHP method to prioritise the requirements, the Quality Function Deployment (QFD) due to its well-established capability in correlating customer requirements with product parameters, its competitors and relationship between the requirements in a single matrix. The relationship between the requirements both covers the strength of relationship and its significance on overall system's performance. Having a single matrix, offering such a visibility allows the engineer to set performance targets which are realistic. In addition, process allows appreciating the difficulty or ease with which a particular target can be achieved by the manufacturer or the owner of the system.

Consequently, for a large problem, use of such tool can generate a large matrix having large number of requirements. Analysing more than 20 requirements results in complex interrelationship and poor appreciation of the effect of those relationships by the user – human brain can connect and correlate up to a certain number of threads. Thus coupled with the complexity of dealing with a large number of user requirements, the benefit of adopting such tools to effectively derive technical specifications is either lost or not fully appreciated without additional tools which can undertake number crunching or problem solving – leading to more complexity and loss of focus on actual problem.

This study seeks to solve the above mentioned problems that are associated with the current product development tools, by combining Kano, AHP, and QFD analysis which is a new approach that deliberates on effective understanding of the customer needs and consequently transform or realise these requirements into a highly innovative and competitive physical product.

Overall, KADDB plans to implement the proposed methodology for the development of any future products in a systematic and in relatively simple steps with high levels of consistency regarding the quality and customer satisfaction

In the future, the proposed methodology considered in this study can be automated by customising the tools according to the problem needs. This will significantly speedup the process of capturing, prioritizing and selecting the most significant customer requirements, while dealing with larger number of customers sample size to fully and accurately capture the future needs of a system to operate in a challenging environment

1.4 Thesis Structure

This thesis is divided into 5 chapters;

Chapter 2 covers the literature review of the product development concept including the techniques and tools used throughout the research work. This chapter introduces the complexity and challenges in designing and developing a new system or a product, it also introduces the tools which have been developed in the past 50 years to aid engineers to better appreciate the user needs for concept development thus allowing the reader to have a better insight on the theoretical background and reasons for selection of such tools in this study.

Chapter 3 introduces the implementation and explains the application of the integrated new product development tools applied to a real life case. The implementation process takes account of the needs, prioritisation, transformation of needs into technical specifications, functional modelling to cover translation of 'Whys' into 'Hows' and the development of physical architecture. This chapter also explains the new integrated technique that has been developed and implemented as part of this research work.

Chapter 4 presents the preliminary and overall results. A separate discussion on preliminary and final results has been offered to emphasise the significance of each stage and tools used for the product development.

Chapter 5 summaries the overall work that has been conducted during this study including the final outcome and achievements. The conclusions and the potential future directions for further research are also covered in this chapter.

2 LITERATURE REVIEW

With the ever evolving product development methodologies, a large variety of tools and techniques have become available to designers to choose from. Yet, despite the great benefits of such evolution, it has also become a relatively complex and confusing task to decide which methodology is the best for any newly developed products. Moreover, in our case, the development of a militarised all-terrain vehicle (MATV) provides additional challenges due to the combination of both automotive and military requirements.

2.1 Chapter Roadmap

This chapter starts with an overview and discussion of the general product development process which includes “understand the opportunity” and “development of a concept” phases.

In the “understand the opportunity” phase, the following two stages are reviewed:

a. The customer need analysis for capturing, segregating, and electing most significant customer requirements. This stage has been accomplished by utilising the AHP and Kano model.
b. In order to correlate the customer requirements with the product parameters, a competitive analysis has been explained for correlating the customer requirements with the product parameters, including the QFD and Design Drivers tools.

While in the “development of a concept” phase, the following two stages are discussed and analysed:

a. The first stage focused on functional modelling in which the functional hierarchy tree is used as the main tool for decomposing the high level user requirements, and driving the actions and technologies for achieving the targeted values of the product.

b. Finally, this chapter concludes by discussing the product architecture as part of the 2nd stage. In this regard clustering technique is used for achieving the modular architecture of a product.

2.2 General Product Development Process

The product development process is the complete group of actions needed to develop a new concept to be ready for marketing or sales. Furthermore, this group starts from the preliminary idea, moving through the business case analysis, marketing, engineering design, manufacturing plans, and product validation (Otto and Wood, 2001).

For comparison, Li et al. (2010) defined product development process as the move from customer requirements to a development of a physical structure bounded by various design constraints.

Moreover, Wang and Lin (2009) noted that, modern product development process involves huge amount of activities, which may be dependent or independent with each other.

However, in order to simplify the process of product development, Otto and wood (2001) divided it into three high level phases as shown in Figure 2-1, namely: (1) understand the opportunity phase; (2) development of a concept phase, and; (3) implementation of a concept phase. These phases of product development are discussed in more detail below:

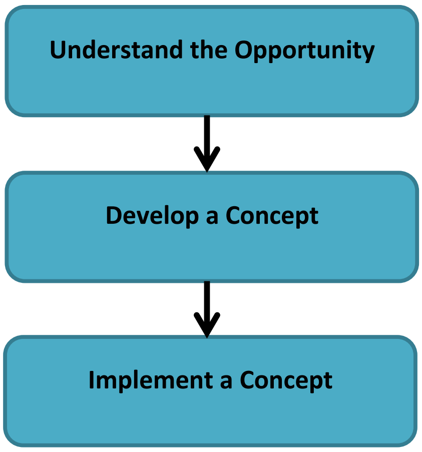


Figure 2-1 General product development phases

Phase1: Understand the Opportunity. This phase, also described as a pre-concept phase (Fox, 1993, p. 185), involves all actions required to launch a new product development effort, including; vision development, market opportunity analysis, customer need analysis, and competitive analysis (Otto and Wood, 2001, p. 15) as shown in Figure 2-2.

As this research study is concerned with the product development methodology, the above two important activities; customer need and competitive analysis have been further discussed in this literature review.

Figure 2-2 Activates within the understand the opportunity phase

Phase2: Concept Development. This is an important step in designing new products (Turan and Badrul, 2013). This phase has been described differently by previous investigators. The engineering research approach describes it as a conceptual design term, in which solution principles are created for the sub-functions (Perttula and Sääskilahti, 2004). Pahl and Baitz (1996) suggest this phase to be "the guideline" for the design; yet, it is worth noting that their deliberations are effective only after agreeing on the solution principle, in terms of functions, which is a part of the conceptual design process.

Otto and wood (2001) on the other hand, represent a wider perspective, as they suggested that this phase consists of all actions needed in deciding the final product. The main activates within this phase include portfolio planning, functional modelling, product architectural development, and concept engineering.

Based on the project focus, the last two actions have been further discussed later in this literature review.

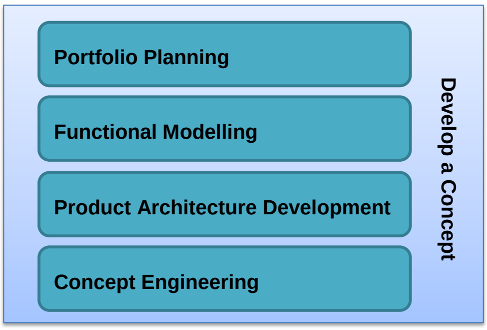


Figure 2-3 Activates within the develop a concept phase

Phase 3: Concept Implementation. In this phase detailed work is carried out to realise the selected concept as shown in Figure 2-4. Furthermore, the majority of this work is achieved through "embodiment engineering" (Otto and Wood, 2001, p 20).

As the work reported here covers the process only up to concept development, this phase is beyond the scope of this study and the author will not discuss the sub-phases of concept implementation further.

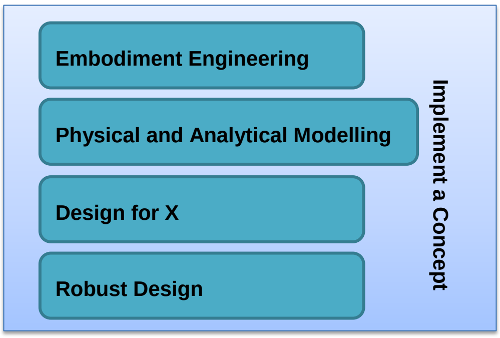


Figure 2-4 Activates within the Implement a concept phase

2.3 Understand the Opportunity Phase

2.3.1 Customer Need Analysis

The success of a system is mainly measured by the extent to which it fulfils its purpose (Hauksdóttir, Mortensen and Nielsen, 2013). In this regard, Gumus and Ertas (2004) argued that one of the key actions in the development of a system is recognising this purpose. Hull, Jackson and Dick (2005) discussed the fact that one of the groups specialising in the IT value research – called the Standish group – conducted a survey which showed that incomplete requirements and weak requirement management are typically elements of the main causes for project failure.

In order to achieve clear needs/requirements that can be understood by marketing and engineering, Jiao and Chen (2006) suggested that customer need analysis should be considered a vital task, with emphasis on the interpretation of the Voice of Customers (VoC) (Griffin and Hauser, 1993).

In addition, providing further insight into these concepts, Kurtadikar et al. (2004) classified customer needs into core and distinctive needs based on the need average weight. The average weight is expressed as the number of times a need is expressed by stakeholders divided by the total number of stakeholders/customers. However, Otto and Wood (2001) presented a more detailed classification of the customer needs including direct needs, latent needs, constant needs, variable needs, general needs, and lastly, niche needs.

Also, Kurtadikar et al. (2004) argued that the core needs are the needs linked to basic functioning of the product and the distinctive needs are the specific needs that are not required for basic functioning of the product, but act as an additional feature.

In this regards, by appreciating the classifications of the customer needs, companies can offer customer-focused products with greater amount of individuality, while maintaining market-focus – all factors which enhance average satisfaction levels (Jiao and Chen, 2006), (Tseng and Piller, 2003).

2.3.1.1 Definition

In general, needs/requirements are defined and divided into diverse requirement types. However, the main two types used within this research, are Functional and Non-Functional Requirements (Hauksdóttir et al., 2013).

- Functional requirements (FRs) are defined as product capabilities or specifications such as top speed, horsepower, weight, etc…
- Non-Functional Requirements (NFRs) specify the product qualities, standards or, more commonly, quality attributes (QAs) such as mobility, survivability, look and feel, etc...

2.3.1.2 General Process

Jiao and Chen (2006) referred to the customer need analysis as customer requirement management; moreover, they noted that in order to accomplish customer satisfaction, the processes must begin with effective capture, analysis, and understanding of the customer's genuine requirements.

Figure 2-5 presents a general overview of the customer requirement management process, incorporating the customer needs in a customer domain, and achieving functional requirements through the following main actions;

1. Requirement elicitation. This includes performing systematic selection and registration of the needs/requirements.
2. Requirement analysis. This action translates the Voice of Customer (VoC) into meaningful requirements to both marketing and engineering.

3. Requirement specification. This action is mainly for defining the product specifications within the functional domain.

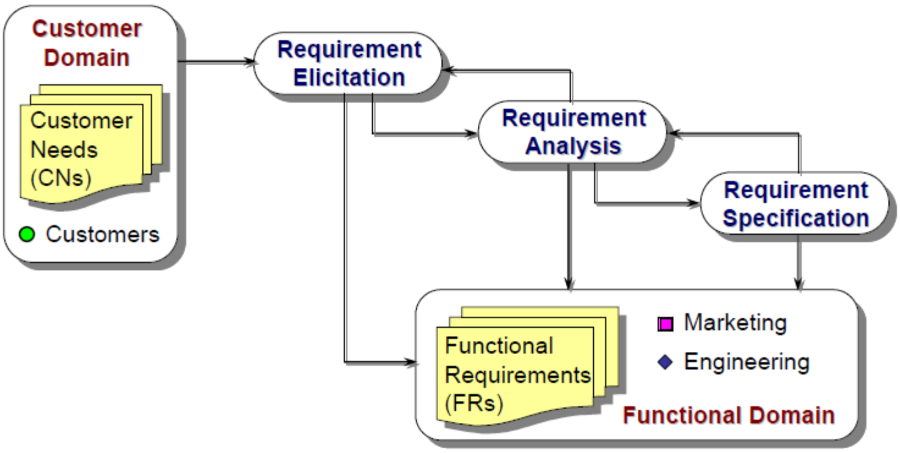


Figure 2-5 General customer requirement management process

Source: (Jiao and Chen, 2006)

2.3.2 Requirements Structuring

Saaty (1980) noted that, when analysing a structure, the number of components and their mutual relations increase such that it becomes difficult to grasp and manage the information of all the individual parts and components. In this regard, Saaty (1980) suggested decomposing larger systems into sub-systems in a hierarchical manner.

IN a similar vein, Hauksdóttir, Mortensen and Nielsen (2013) explained that hierarchical structuring includes generating a decomposition structure of objects tree – e.g. breaking down the larger system as suggested by Saaty.

Based on the above, it is apparent that large groups of customer requirements can be simplified by using hierarchical structuring, in order to facilitate the start of the elicitation process for the requirements, as discussed earlier in section 2.3.1.1.

Leighton, Gierl and Hunka (2004) have suggested four forms of hierarchical structures including Linear, Convergent, Divergent, and Unstructured, as shown in Figure 2-6.

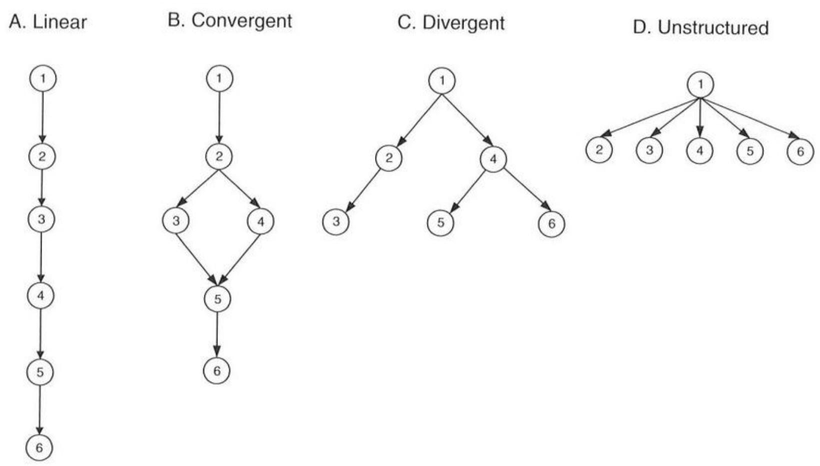


Figure 2-6 Four types of hierarchical structures

Source: (Leighton et al., 2004)

The Linear, Convergent, and Divergent are considered as structured type of hierarches, whereas the forth type is unstructured as the name implies. Moreover, the linear type is used when there is only one option in terms of successive attributes – meaning that are fully dependent on each other, leading to just one expected result. An example of such a scenario would be a series of commands in a software program with only one approach to reach the final result.

The Convergent type of hierarchy also ends with one result, in the same manner as the linear type. However this result can be achieved via different paths – analogous to a route map with different paths between two defined locations (the starting and ending – or resultant – points).

Regarding the Divergent type, this hierarchy is implemented when more results are required through the implementation of different arrangements of attributes. This type was implemented during this study for arranging the customer requirements in the implementation section.

The final type (the unstructured hierarchy) is considered an extreme case, where different results that can each can be achieved by only one attribute. An example would be multiple route maps to different locations from a single starting point.

2.3.3 CR Analysis and Selection-Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) was developed by T. L. Saaty (1980), The AHP was an outcome of his experience while leading several major research projects within the US Arms Control and Disarmament Agency (Bhushan and Rai, 2004).

As one of the most extensively used multiple principles decision-making tools, the AHP, has been a major implement at the hands of decision makers and researchers (Vaidya and Kumar, 2006) to enable them establish customer needs priorities.

Vargas (1990) defined AHP, as a measurement theory that deals with one or both of measurable and immaterial standards. It was also highlighted that it can deal with a large number of applications such as, decision theory, brain models, and conflict resolution.

Finally, Karlsson and Ryan (1997) argued that AHP with its comparison approach using a pairwise technique embraces significant redundancy, which makes it less delicate to judgmental errors commonly found in other techniques that use absolute assignments.

2.3.3.1 General Methodology

Bhushan and Rai (2004) outlined the fact that within the AHP, a given problem is decomposed into a sub-problem based hierarchy in order to allow it to be more easily understood and subjectively assessed, as the subjective assessments are transformed into numerical measures. Moreover, they explained the general methodology of the AHP in the following stages;

Stage 1: a hierarchy consisting of objectives, criterion, sub-criterions and alternatives is obtained by decomposing the problem (Saaty, 1980).

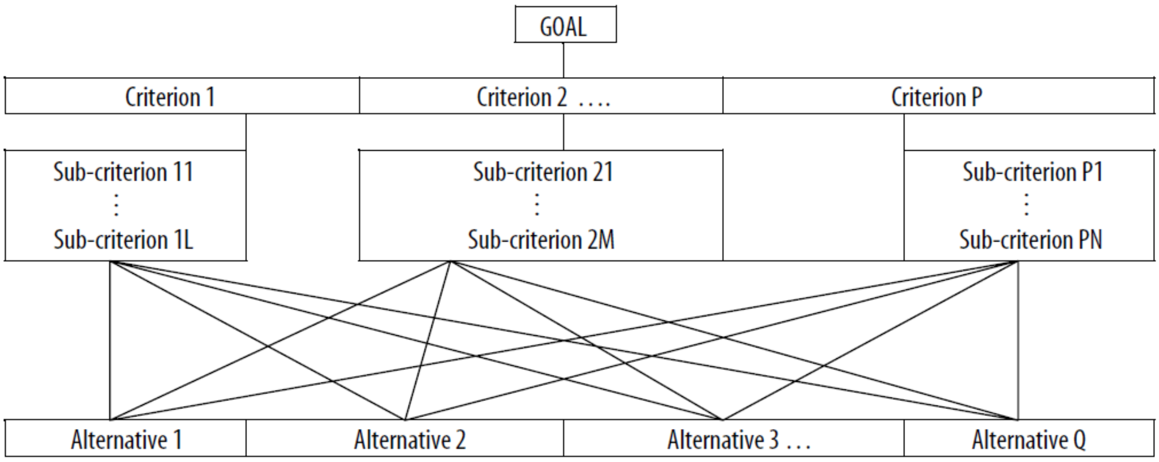


Figure 2-7 General hierarchy structure (Bhushan and Rai, 2004)

As shown in Figure 2-7, the objective or goal of the problem is placed at the top level of the hierarchy, whereas, in the middle, several criterions, and sub-criterions are generated, and lastly, at the lowest level of the hierarchy, are the alternatives to be compared.

Stage 2: based on the generated hierarchy structure, data gathering from experts and decision-makers is performed in terms of pairwise alternatives comparison as shown in Figure 2-8

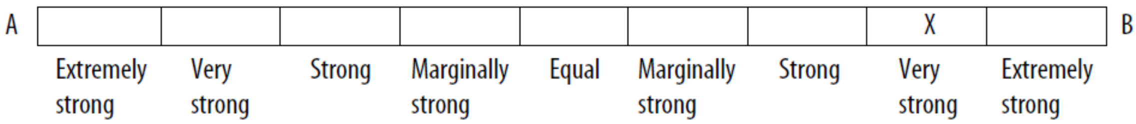


Figure 2-8 Pairwise comparisons setup (Bhushan and Rai, 2004)

Bhushan and Rai (2004) demonstrated an example, considering a questionnaire pairwise comparisons setup ranging from extremely strong for the 'A' side to extremely strong for 'B' side as shown in Figure 2-8, if the "Very strong" box is assigned with "X" then it is interpreted as "B is very strong compared with A", later on, such results were translated into qualitative figures as shown in Table 2-1.

Table 2-1 Quantitative comparison degree scale

Verbal judgments	Numerical scale of the degree of preference
Equally preferred	1
Moderately preferred	3
Strongly preferred	5
Very Strongly preferred	7
Extremely preferred	9
For compromise between the above values	2, 4, 6, 8

Source: Saaty, 1996.

Stage 3: Theeranuphattana, Tang and Khang (2012) explained that a square pairwise comparison matrix $[A]_{nxn}$ is generated based on deferent criterions a_{pq}, were a value of 1 is assigned for the diagonal elements, and the element q importance related to element p is the reciprocal of a_{pq}. This arrangement is shown in the following matrix;

$$[A]_{n\times n} = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{12} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1 \end{bmatrix}_{n\times n} \qquad \textbf{(2-1)}$$

By solving the following matrix equation, the local priorities are determined, e.g. (Saaty, 1980)

$$[A]_{n\times n}[W]_{n\times 1} = \lambda_{\max}[W]_{n\times 1} \qquad \textbf{(2-2)}$$

Where $[W]_{nx1}$ represent the normalised eigenvector, and λ_{max} is the principal eigenvalue of matrix$[A]_{nxn}$.

Furthermore, Theeranuphattana, Tang and Khang (2012) noticed that from this equation, $[W]_{nx1}$ offers the criterions priority ordering, while λ_{max} is considered a consistency measure of the decision.

Stage 4: the weights of the sub-criterions are multiplied with the rating of each alternative, and then combined in order to generate the local rating with regard to each criterion. Later on, the weights of each criterion are multiplied with the local ratings and combined to generate global ratings.

Finally, for each alternative, a weight value is produced founded on the arbitrated importance of one alternative relative to another with regards to a common criterion.

2.3.3.2 Partial Implementation of AHP

In some cases, a partial utilisation of the AHP has been performed, due to the nature and number of user requirements generated leading to these needing to be prioritised and selected.

Salgado, Salomon and Mello (2012) argued that, AHP is not applicable for all types of hierarchies, based on that, this tool was not able to prioritise activities within the new product development process, which has a different hierarchy (see Figure 2-10) form the standard one as shown in Figure 2-9. Moreover, they indicated that for the new product development process, each alternative is related to a single criterion, as each activity is achieved during only one macro-activity model.

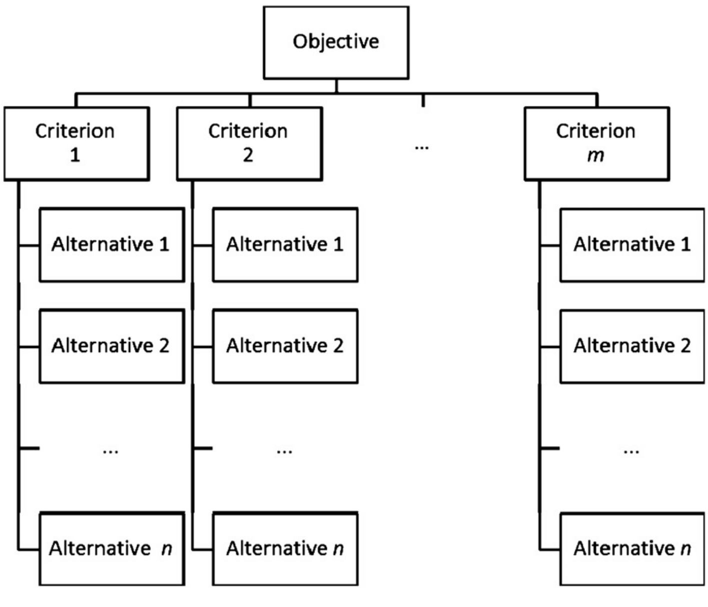


Figure 2-9 Common hierarchical structure used for AHP

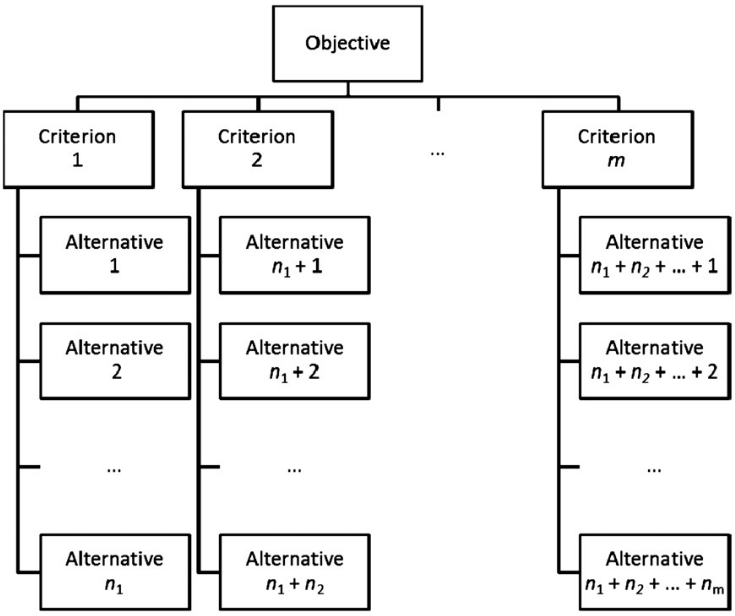


Figure 2-10 Hierarchical structure with alternatives relating to a single criterion

Source: (Salgado et al., 2012)

Based on the hierarchical structure with alternatives relating to a single criterion, the global weight for each alternative is calculated by multiplying its relative weight with its corresponding criterion, rather than multiplying with all criterions as is the case for the standard AHP (Salgado et al., 2012).

2.3.4 CR Analysis and Selection- Kano Model

This method was developed by Professor Noriaki Kano and his colleagues; Kano's model is a valuable tool for understanding customer needs and their influence on customer satisfaction (Kano et al., 1984). Moreover, Wang and Ji (2010) noted that different Customer Requirements (CRs) are classified within the model, based on their level of achievement of Customer Satisfaction (CS).

2.3.4.1 Kano Diagram

The Kano model consists of three forms of relations between the level of CS and the achievement level of CRs, namely must-be, one-dimensional and attractive (Kano et al., 1984). These relations are plotted in three curves as shown in Figure 2-11. The horizontal axis in the Kano diagram shows the achievement level of CRs, while the vertical axis represents the CS level or dissatisfaction.

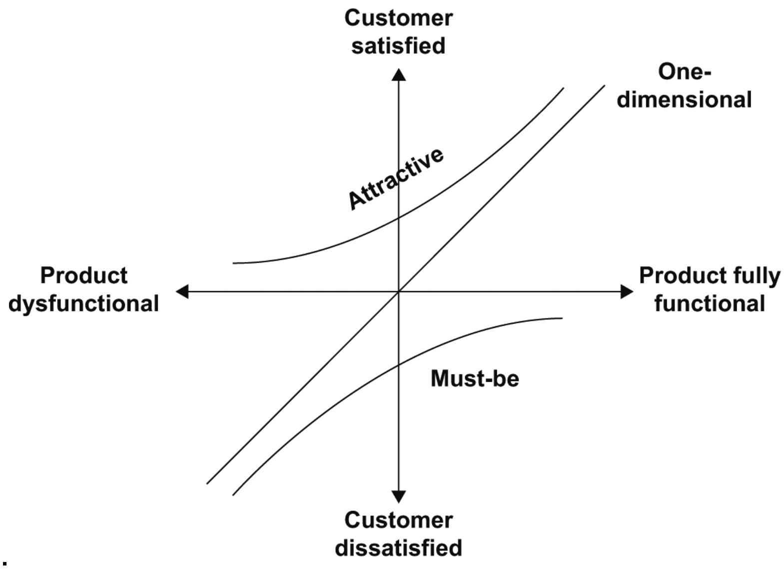


Figure 2-11 Kano diagram (Kano et al., 1984)

Based on the positions shown in the diagram, the three relations are further described by Wang and Ji (2010) as the following;

- Must-be requirements are taken for granted by the customers when achieved; however, customers will be dissatisfied if the product fails to fulfil these requirements.
- One-dimensional requirements are linearly related by their achievement to the customer satisfaction level, that is, the greater the level of achievement, the more satisfied the customer is and vice versa. Moreover, they are usually clearly required by the customer (Sauerwein et al., 1996).
- Attractive requirements will result in higher than proportional satisfaction, but if not achieved, the customer is not dissatisfied

Wang and Ji (2010) further added that there are extra three relations of the CRs, including indifferent, questionable, and reverse. In this regard, the indifferent classification indicates that customers are uninterested about the requirement in question whether or not it is achieved, whereas questionable means a contradiction to the question posed by the customers, and finally, reverse, indicating that the customer totally dislikes the requirement.

2.3.4.2 Kano Questionnaire

The six Kano categories are classified using a special purpose questionnaire (Sauerwein et al., 1996). Wang and Ji (2010) explained that each CR is inspected by pairwise questions including functional and dysfunctional forms. Each of the two possible answers consist of one of five options including; must-be, like it, one-dimensional, neutral, live with and dislike as shown in Figure 2-12.

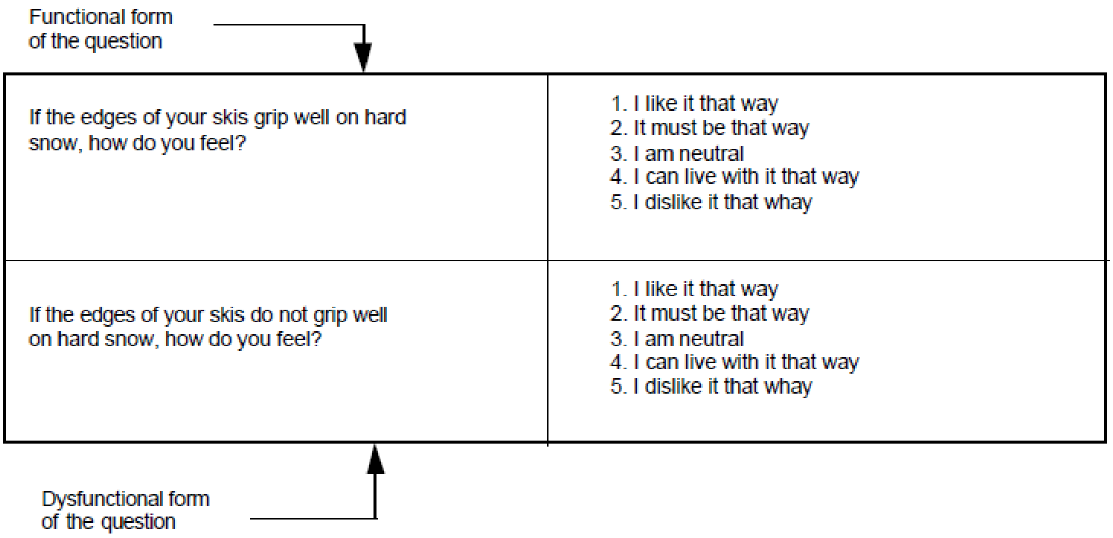


Figure 2-12 Kano questionnaire – functional and dysfunctional question forms

Source: (Sauerwein et al., 1996)

Sauerwein et al. (1996) indicated that once the two answers are combined, the features of the product can be categorised using the evaluation table shown in Figure 2-13. Kano et al.(1984) explained that in general, the final Kano category for the CR is set by the most recurrent observations of the sample set of responses.

Customer requirements → / Functional (positive) question ↓	Dysfunctional (negative) question: 1. like	2. must be	3. neutral	4. live with	5. dislike
1. like	Q	A	A	A	O
2. must-be	R	I	I	I	M
3. neutral	R	I	I	I	M
4. live with	R	I	I	I	M
5. dislike	R	R	R	R	Q

Customer requirement is ...

A: Attractive
M: Must-be
R: Reverse

O: One-dimensional
Q: Questionable
I: Indifferent

Figure 2-13 Evaluation table

Source: (Sauerwein et al., 1996)

Moreover, Sauerwein et al. (1996) added that it is beneficial to include a (self-stated) importance on a Kano questionnaire, in order to set the priorities for the product development process as shown in Figure 2-14

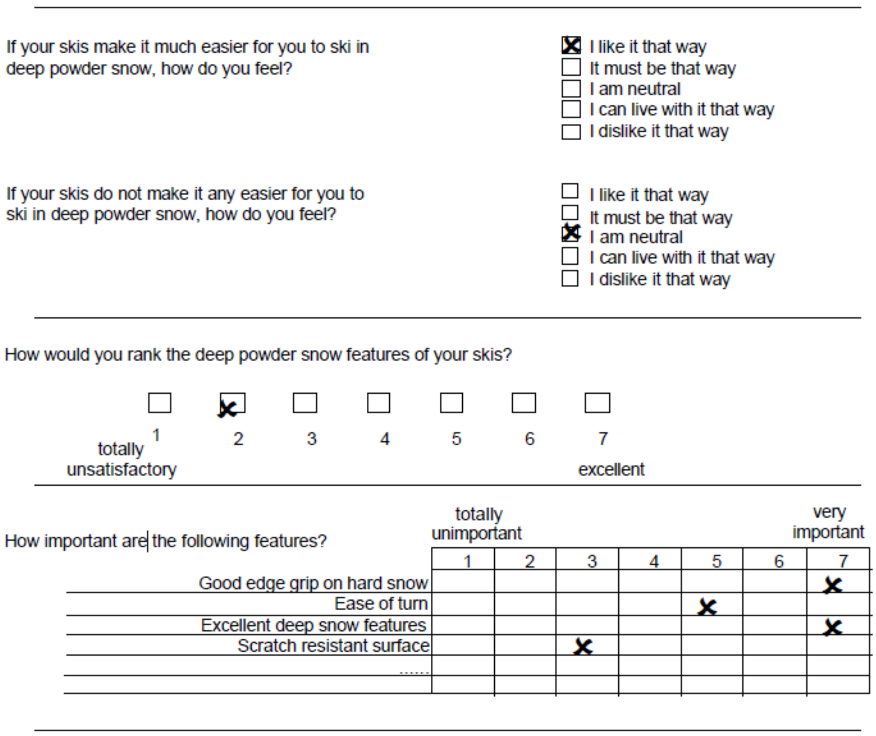


Figure 2-14 Kano questionnaire, self-stated-importance

Source: (Sauerwein et al., 1996)

2.3.4.3 Assessment

The assessment process of the questionnaire is achieved in three stages. The first stage includes combining the answers of the questions; next, the evaluation table is employed to classify the answers as previously shown in the Figure 2-13, before lastly, the now-classified answers are listed in a results table for further analysis as shown in Figure 2-15

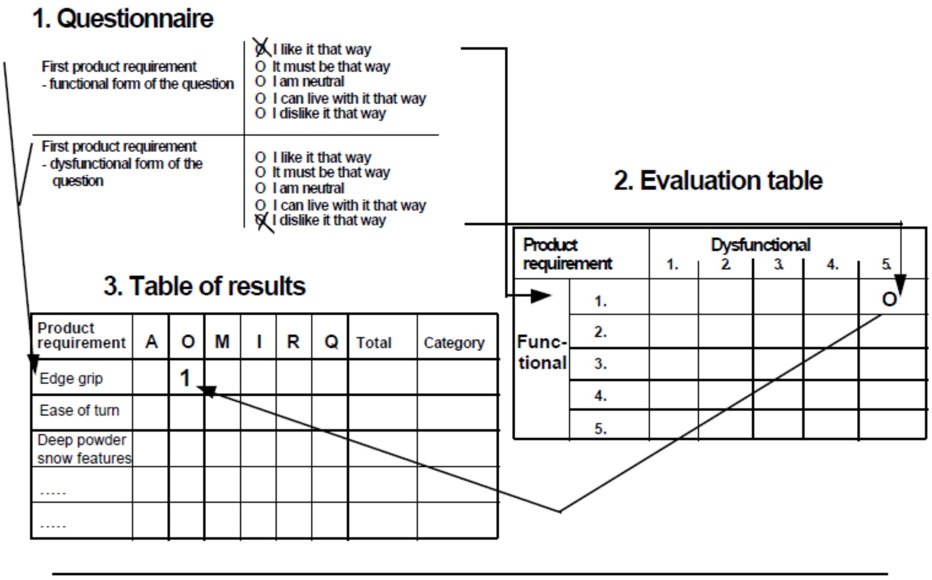


Figure 2-15 Assessment process

Source: (Sauerwein et al., 1996)

2.3.4.4 Customer Satisfaction Coefficient

Berger et al. (1993) highlighted the fact that the CS coefficient indicates whether the customer satisfaction can be improved or not, by achieving the product requirements.

The average impact on satisfaction or dissatisfaction can be calculated using the following equations respectively (Berger et al., 1993).

Degree of satisfaction:

$$\left(\frac{A + O}{A + O + M + I}\right) \qquad \textbf{(2-3)}$$

Where A is Attractive, O is One-Dimensional, M is must-be, and I is Indifferent requirements

Degree of dissatisfaction:

$$\left(\frac{O + M}{A + O + M + I}\right) \times (-1) \tag{2-4}$$

The minus sign is used in equation **(2-4)** to indicate the negative effect on CS if this product quality is not achieved.

Moreover, Sauerwein et al. (1996) explained that on one hand, the positive CS-coefficient with range starts from 0 until 1; e.g. as the value approaches 1, the customer becomes more satisfied. However, when approaching a value of 0, the customer becomes less satisfied with the achieved requirement. On the other hand, if the negative CS-coefficient approaches -1, the customer dissatisfaction is strongly affected when the product requirement is not achieved. Finally, the 0 value indicates a neutral influence on the customer when the requirement is not achieved.

Finally, Sauerwein et al. (1996) presented a sample CS-coefficient graph as shown in Figure 2-16.

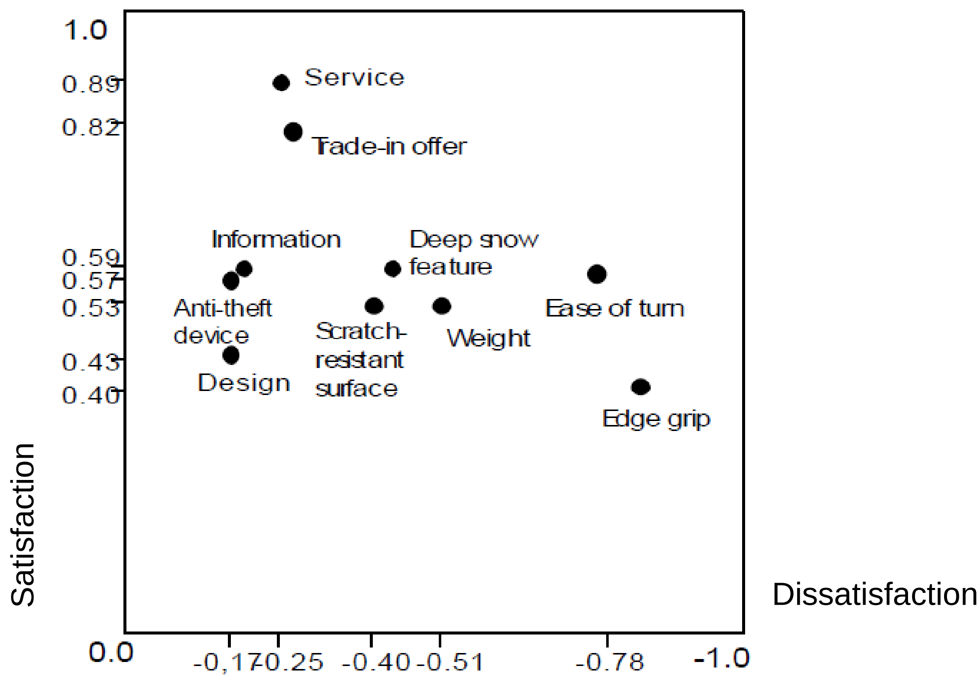


Figure 2-16 Product features effect on satisfaction or dissatisfaction

Source: (Sauerwein et al., 1996)

2.4 Competitive Analysis

Zahra and Chaples (1993) have described the competitive analysis as the process of outlining and comprehending a company's own industry, including governing competitor's strengths and weaknesses, classifying rivals, and expecting their moves.

In that essence, the competitive analysis is considered a critical part within the product development course, as the individuality of the product or service can be recognised and therefore the vital requirements and specifications for the targeted market can be identified (Otto and Wood, 2001).

Moreover, one of the main tools used during the competitive analysis is benchmarking, as it is a tool for improvement that can be accomplished through comparison with other products that are considered the best in the market (Khurrum S. Bhutta, Faizul Huq, 1999). After product benchmarking, the targets are set for the development of the product as part of the next development stage (Otto and Wood, 2001).

In this regard, the Quality Function Deployment (QFD) technique is used as one of the main tools to establish the relationship between CRs and technical specifications along with their target values to ensure product competitiveness (Otto and Wood, 2001).

In this study, the design driver method has been used along with QFD which is discussed next. Functional requirements have been finalised using this technique.

2.4.1 Design Drivers

Design drivers is a method used as a primary decision making process according to Otto and Wood (2001); moreover, these authors explained this technique as the following;

The main process consists of the following activities:

- The two fundamental views are considered to generate two loops for determining the design driver:
    1. The business revenue, customer, or market risk view
    2. The physical, engineering, or technological risk view
- The design drivers for the product are then considered under the above two fundamental views
- Both the views are considered as an independent source of risk for any new product development project
- Both the views form two product development decision-making efforts that intersect at the key design decisions to be made
- The first loop (the business case loop) can be developed with an effective understanding of the customers' needs
- The business case loop starts with an end-node of the business objective: "market share" or "profit", and consists of two half's:
    1. Revenue side - comprising the following nodes:
        - The first set of nodes determines what can permit an increase in important customer needs or functional specifications
        - Subsequent nodes determine what can permit this increase of the customer needs in terms of the concept design decisions
    2. Cost side – which considers changes in the design decisions that will cause cost fluctuations, which will potentially change the end node of profit

- For the engineering (second) loop, the process outlined above is repeated for the designs technical constraints based on answers from the technical questions given in Table 2-2.
- The process starts by listing the major performance constraints that must be met; key questions include:
    1. What physical constraints will be imposed on the design from just being low cost and high performance as requested by the business viewpoint?
    2. Which two competing aspects may cause the constraint?
- The process is continued in reverse until the concept design decisions are reached
- The engineering loop consists of two halves:
    1. Constraint side.
    2. Permit side

- The intersect of the business and technical constraint loops by the common design variables subsequently provides an understanding of the underlying drivers

Table 2-2 Technical questions to clarify state of comprehension of a design

What is the problem really about?
What implicit expectations and desires are involved?
Are the stated customer needs, functional requirements, and constraints truly
Appropriate?
What avenues are open for creative design and inventive problem solving?
What avenues are limited or not open for creative design? Limitations on scope?
What are the technical and technological conflicts inherited in the design task?

Source: (Otto and Wood, 2001)

2.4.2 Quality Deployment Function, QFD

Mehrjerdi (2010) outlined the idea that identification of the customer requirements and subsequent translation into engineering design requirements will lead to a successful new product development process.

In this regard, the Quality Function Deployment (QFD) was developed as a very powerful tool that translates the voice of the customer into technical or design specifications (Jaiswal, 2012). Similarly, Tran and Sherif (1995) indicated that for gathering and conveying the Voice of the Customer (VOC) to production, the QFD technique is used as it delivers the goals in an organised procedure.

The concept of QFD was developed in Japan in 1967, and is defined as translating the customer needs (Whats) in to quality characteristics (Hows), before generating a quality plan for the final product by systematically arranging the relations between customer demands and the quality characteristics (Prasad, 1998). Moreover, Kumar, Antony and Dhakar (2006) noted that what is called a House of Quality (HoQ) is the core of the QFD methodology as shown in Figure 2-17

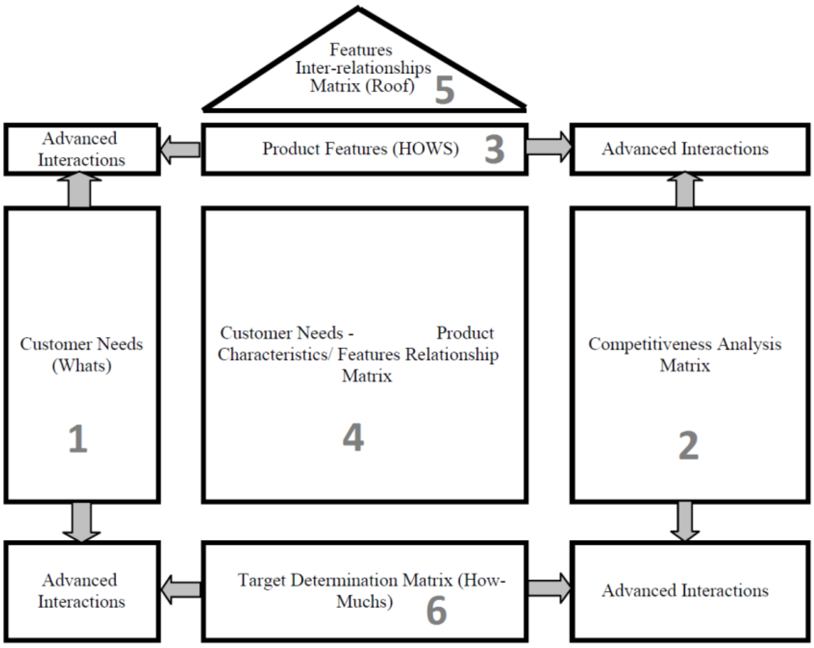


Figure 2-17 House of quality

Source: (Kumar et al., 2006)

2.4.2.1 QFD Phases

Jaiswal (2012) indicated that a comprehensive QFD consist of four phases as shown in Figure 2-18;

Phase 1, Product Planning: this phase is also known as House of Quality; the customer requirements are interpreted into product technical requirements in order to fulfil them.

Phase 2, Part Deployment: in this phase the technical requirements are interpreted into the main part characteristics.

Phase 3, Process Planning: in this phase, the main process operations are recognised which are essential for achieving the main part characteristics.

Phase 4, Production Control: this phase, also known as Process Control, is that in which the control, maintenance, and training plans are established in order to control operations.

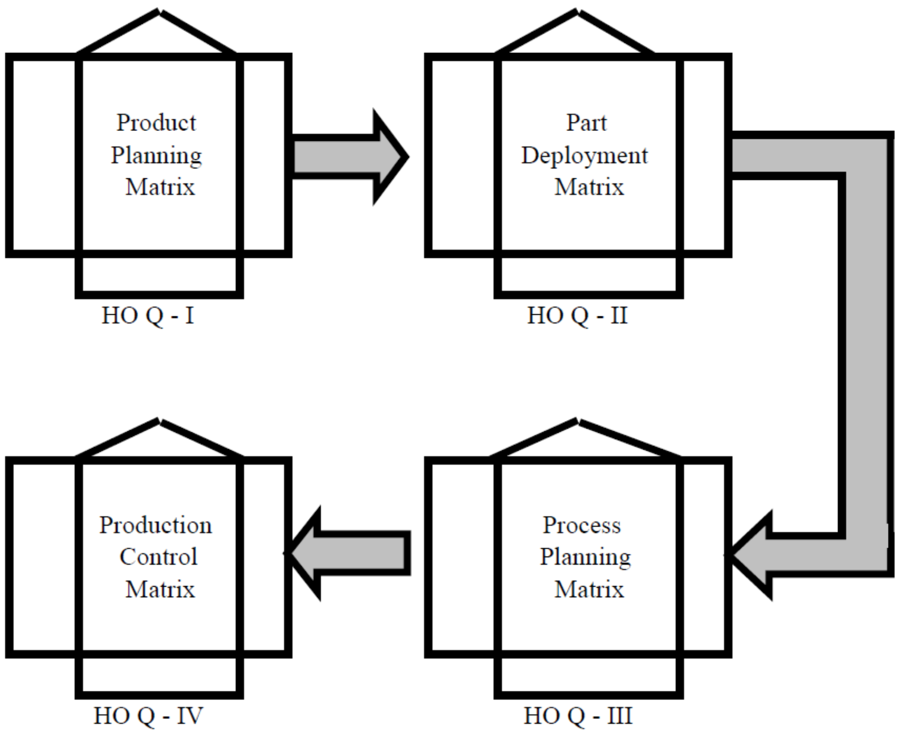


Figure 2-18 Phases of comprehensive QFD

2.4.2.2 House of Quality Structure

The House of Quality is the first phase in the development of the Quality Function Deployment process (Hauser and Clausing, 1988). Moreover, Kumar, Antony and Dhakar, (2006) showed that it is composed of six main sections, as shown in Figure 2-17.

In that regards, Creative Industries Research Institute (2007) explains this structure as the following;

Section 1. Customer Needs; also called 'Voice of the Customer' or 'Whats'. This section consists of two main tables (located in zone 1 in Figure 2-17, also shown in Table 3-23 and Table 3-24 in the Implementation section);

a. Customer Requirements; the important customer requirements are tabulated in the left most column.
b. Customer Importance Ratings; this contains the importance of each requirement based on a 1-5 scale used by the customers.

Section 2. Competitiveness Analysis; these are graphically presented to rate an in-house product with its competitors; it is located in zone 2 in Figure 2-17, also shown in Table 3-27 and Table 3-28 in the Implementation section.

Section 3. Product Features; also known as 'Systems Specifications' or 'Voice of the Engineer' or 'Hows', this section consists of two tables (located in zone 3 in Figure 2-17, also shown in Table 3-30 in the Implementation section);

a. Technical Descriptors, containing the product or service attributes that can be measured and benchmarked relative to competition.
b. Improvement Direction, which shows a visual arrow sign indicating the direction of improvement for each technical descriptor.

Section 4. Relationship Matrix; this matrix represents the relation between the customer's needs and the company's capability with regard to those needs. The relationship is expressed as weak, moderate, or strong with a numeric value of 1, 3 or 9 respectively (located in zone 4 in Figure 2-17, also shown in Table 3-31and Table 3-32 in the Implementation section).

Section 5. Correlation Matrix; with a shape like a roof, this matrix is the source of the "House of Quality" term. Moreover, this is where the impact of the technical descriptors on each other is tested through assigning strong positive, positive, negative, and strong negative relationships. It can be expressed as Hows vs Hows. (located in zone 5 in Figure 2-17, also shown in Table 3-33 in the Implementation section)

Section 6. Specification targets; this section consists of four parts (located in zone 6 in Figure 2-17, also shown in Table 3-34 and Table 3-35 in the Implementation section);

a. Organisational Difficulty; in this table, the design attributes are rated in terms of the difficulty of implementation within the organisation.
b. Competitor Products Technical Analysis; this section compares in-house product technical descriptors with the competitors.
c. Technical Descriptors Target Values; also called 'how much', which allow for the allocation of real values for the technical descriptors.
d. Absolute Importance; this part represents the total importance of a technical descriptor by multiplying the cell value with the customer importance rating.

Creative Industries Research Institute (2007) indicated that in order to achieve the comprehensive QFD, phase 2, phase 3, and phase 4 QFDs can be developed in almost the same way as the Phase 1 QFD but in a simplified manner. Moreover, for phase 2, the voice of the engineer is translated into part design specifications, then for the phase 3, the voice of manufacturing planning is achieved through translating part design specifications, and finally, the voice of production planning is achieved through translating the voice of manufacturing in phase 4.

During the introduction of this research work it was stated that over the years, engineers have developed tools to aid them in better design and development of a product. Most of these tools or methodologies were initially developed to solve a particular problem and then generalised to help the engineering and scientific community. At times, generalisation leads to certain shortcomings or weakness in a methodology. The Kano, AHP and QFQ analysis are no different in this respect and offer some limitations such as QFD analysis becomes complex and cumbersome when there are large numbers of requirements. It has been suggested by number of users to break the problem into further sub segments and establish a matrix having no more than 20 requirements per matrix(Creative Industries Research Institute, 2007). Similarly the accuracy and judgment or prioritisation in AHP analysis depends upon the subject matter experience of the user. In addition, both AHP and Kano model require a large sample size to average out any biasness.

In order to overcome and or manage the above limitations such as any biasness towards particular characteristics due to small sample size, both Kano and AHP processes have been employed to verify and complement the outcomes. Similarly, customer requirements have been prioritised and characterised using AHP and Kano, modelling have been evaluated using separate QFD matrix. This again allowed verification between the two approaches and target values. The details of Integrated Dual Mode QFD analysis are fully described in section 3.3.2.1

2.5 Functional Modelling

Functional modelling is considered one of the early tasks in the concept development phase, during which the product action needed to achieve customer satisfactions is determined regardless of how it is deployed (Otto and Wood, 2001).

Eckert et al. (2011) argued that for numerous well-established design methodologies, the functional descriptions of new or current products are the core tool used during those methodologies. They also highlighted the fact that ideas of function at primary design stages can be utilised to clarify the services to be offered by the product as well as the way to manufacture it.

Otto and Wood (2001) highlighted that the functional modelling utilises the customer needs as a starting point in order to develop the product functional map as a final result. Furthermore, they indicated that one of the techniques used in the functional modelling phase is the “Function Hierarchies or Trees”, as the hierarchy of functions is generated by starting with the high-level function of the product as a hierarchy core.

Figure 2-19 represents a standard function hierarchy that can be used for a product. The micro or basic functions (lowermost level) characterise the refined functions aimed to satisfy the customer needs. Moreover, they are an incremental derivative resulting from the decomposition of the high-level function in to primary function carriers or sub-functions, which can be further, decomposed using the proposed function vocabulary as shown in Table 2-3.

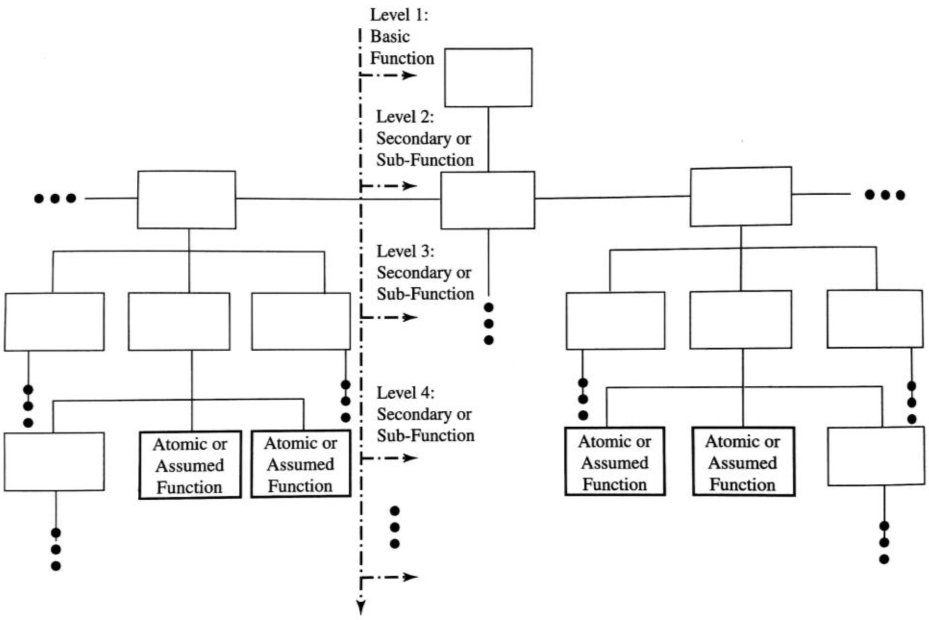


Figure 2-19 Standard function hierarchy

Source: (Otto and Wood, 2001)

Table 2-3 Proposed function vocabulary

Class	Basic	Flow class restricted	Synonyms
channel	Import		Input. Receive. *Allow.* Form Entrance. *Capture*
	Export		Discharge. Eject. Dispose. Remove
	Transfer	Transport (M)	Lift. Move
		Transmit (E)	Conduct Convey
	Guide	Translate	Direct. Straighten. Steer
		Rotate	Turn. Spin
		Allow DOF	Constrain. Unlock
support	Stop		Insulate. Protect. *Prevent.* Shield. Inhibit
	Stabilise		Steady
	Secure		*Attach.* Mount. Lock. Fasten. Hold
	Position		Orient. Align. Locate
Connect	Couple		Join. Assemble. *Attach*
	Mix		Combine. Blend. Add. Pack. Coalesce
Branch	Separate		Switch. Divide. Release. Detach. Disconnect. Disassemble, Subtract. Valve
		Remove (M)	Cut. Polish. Sand. Drill. Lathe
	Refine		Purify. Strain. Filler. Percolate. Clear
	Distribute		Diverge. Scatter. Disperse. *Diffuse.* Empty
	Dissipate		Absorb. Dampen. Dispel. *Diffuse.* Resist
Provision	Store		Contain. Collect. Reserve. *Capture*
	Supply		Fill. Provide. Replenish. Expose
	Extract		
Control magnitude	Actuate		Stan. Initiate
	Regulate		Control. *Allow. Prevent.* Enable/Disable. Limit. Interrupt
	Change		Increase. Decrease. Amplify. Reduce. Magnify. Normalise. Multiply. Scale. Rectify. Adjust
	Form		Compact. Crush. Shape. Compress.. Pierce
Convert	Convert		Transform. Liquefy. Solidify. Evaporate. Condense. Integrate. Differentiate. Process
Signal	Sense		Perceive. Recognise. Discern. Check. Locate
	Indicate	'	Mark
	Display		
	Measure		Calculate

2.6 Product Architecture

Once the functional modelling is achieved, a number of options for grouping these functions into real subassemblies become available. Additionally, with the interface analysis of such subassemblies, the product architecture process is represented (Otto and Wood, 2001).

Whitney (2004) defined product architecture as the process of achieving physical portions through arranging the product functional elements and by which these portions interact. In another definition, Otto and Wood (2001) expressed that the product architecture is the transformation of customer needs into achievable product concepts, that is, achieving product form or physical components through mapping product functions (Muffatto and Roveda, 2002; Ulrich, 1995).

Moreover, Whitney (2004) argued that based on the above definition a link is established between architecture and system level design and also with the principles of system engineering.

Finally, Otto and Wood (2001) suggested that appreciation of different configurations of product architectures will motivate new concepts. Similarly, Whitney (2004) indicated that insightful effects are generated by the architecture in terms of the way the product is designed, manufactured, traded, mended, etc.

2.6.1 Types of Architectures

Otto and Wood (2001) indicated two types of architectures:

1. Portfolio architectures; this type involve a family or selection of products, with the main concern of finding the best way and form for sharing parts between products of the same portfolio.
2. Product architectures; this type is restricted to an explicit product layout

Regarding the product architecture, Ulrich (1995) showed that there are two main categories for this type;

1. **Modular Architecture**: this category is achieved by performing single one-to-one mapping of the functional elements towards the product physical parts, including the specification of the de-coupled interfaces among the parts. Moreover, Ulrich (1995) presented an example of a modular trailer in order to demonstrate this concept as shown in Figure 2-20.

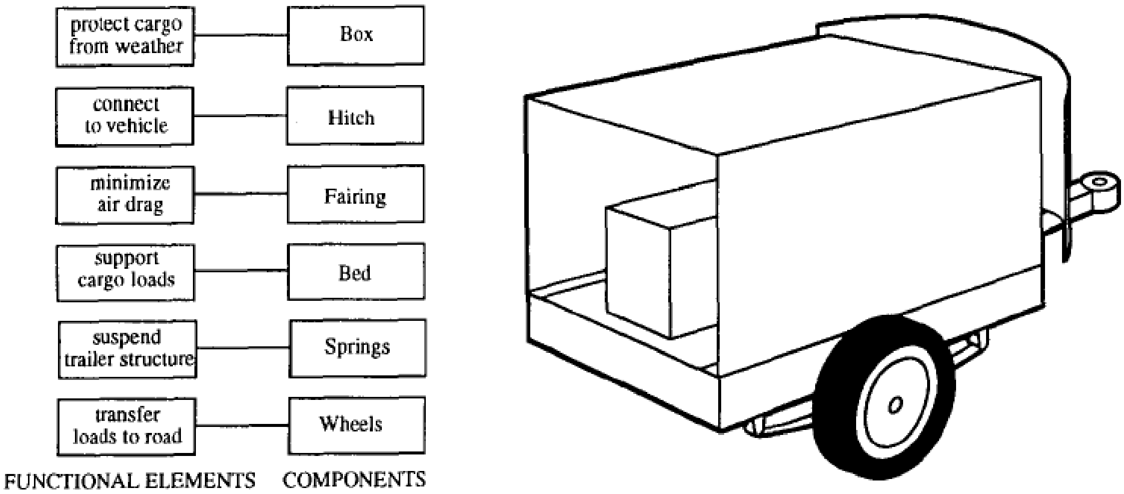


Figure 2-20 Modular architecture – trailer architecture example

2. **Integral Architecture:** this category involves a more complex approach, where the functional elements are mapped using (multi one-to-one) connections to physical parts and/or coupled interfaces between parts. As Ulrich (1995) demonstrated, in an integral trailer example this takes the form shown in Figure 2-21.

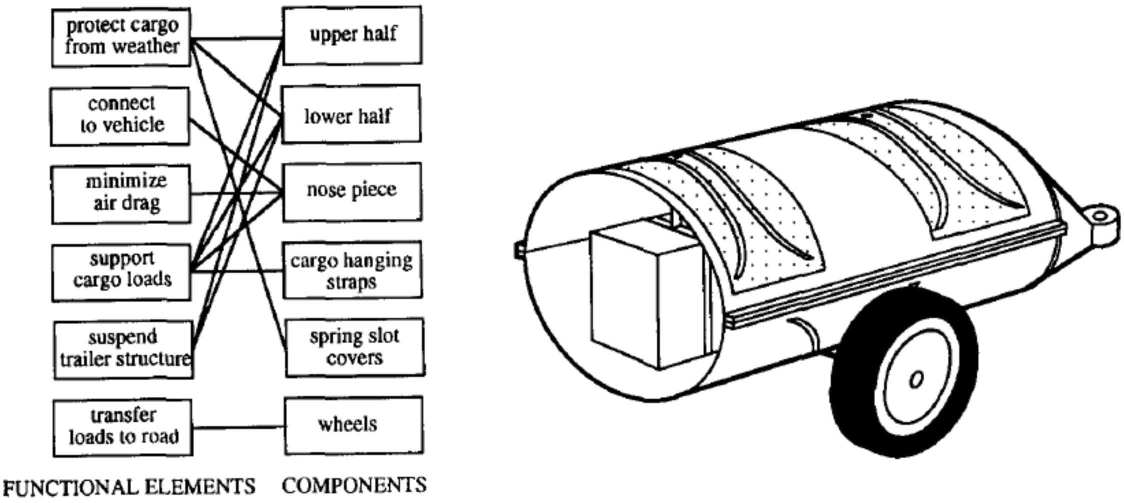


Figure 2-21 Integral architecture – trailer architecture example

2.6.2 Interface Coupling

Ulrich (1995) argued that for coupled parts, when one part is changed, that this will imply that the other part needs to be changed so that the whole product works properly. Therefore, physical parts which are interface connected are nearly constantly coupled to some degree.

As touched upon in the previous section, modular architectures comprise interfaces with de-coupled parts, whereas integral architectures consist of coupled interfaces, a concept demonstrated in the trailer box and trailer bed example shown in Figure 2-22.

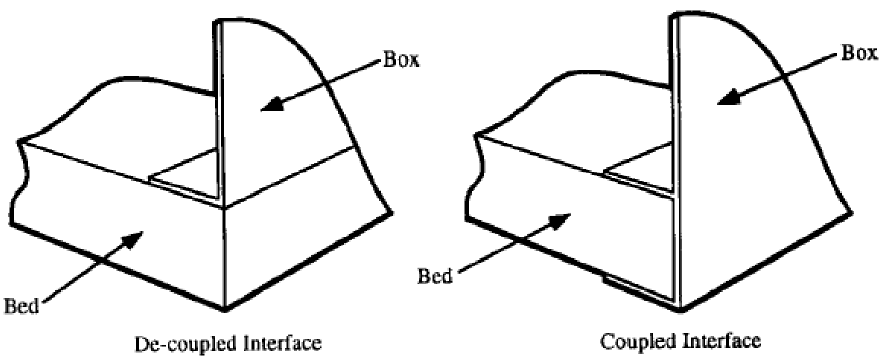


Figure 2-22 Trailer box and trailer bed interface example

2.6.3 Modular Architectures Types

Otto and Wood (2001) divided modular architectures in to two main types;

1. Function-based modularity, with this type applied to divide the product functionality and to determine the distribution of those functions.

2. Manufacturing-based modularity, linked to the product manufacturing and assembly. Moreover, in order to simplify the manufacturing process, parts bundling may be used.

For the purpose of the research, the literature review will cover the function-based modularity.

2.6.4 Function- Based Modularity

This type of modularity consists of four types (Otto and Wood, 2001; Ulrich, 1995);

1. **Slot Modularity**; this type allows a standard devise to perform multiple jobs via the use of a number of parts that can be attached to it consecutively, as illustrated in Figure 2-23.

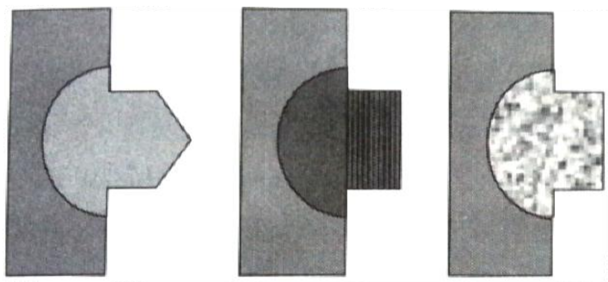


Figure 2-23 Slot modularity

2. **Bus Modularity**; this type allow a standard devise to be upgraded in terms of functionality and performances through having a standard interface that allow for the inclusion of a number of different parts as shown in Figure 2-24.

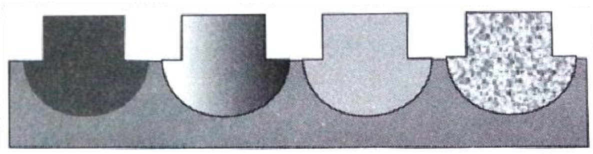


Figure 2-24 Bus modularity

3. **Sectional Modularity**; this type allows a devise to perform multiple jobs through using a number of parts that are permanently attached or chained to it using a standard interface such as the Swiss tool, as illustrated diagrammatically in Figure 2-25.

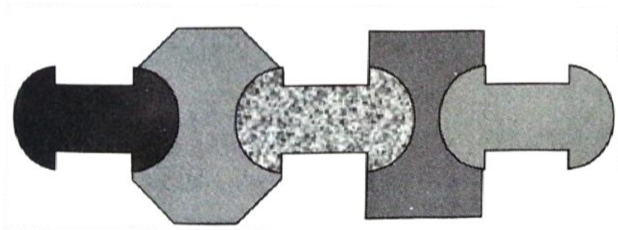


Figure 2-25 Sectional modularity

4. **Mix Modularity**; this type allows to the generation of a number of devices using multiple standard parts that are connected together through module webs instead of a basic chain as illustrated in Figure 2-26.

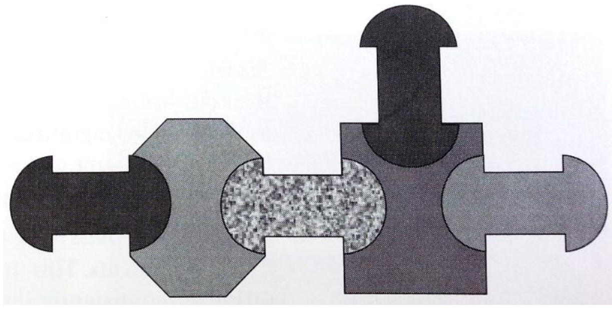


Figure 2-26 Mix modularity

2.6.5 Modular Design – Clustering Method

Otto and Wood (2001) indicated that this method is considered one of the basics for generating modular product architecture; moreover, they discussed the fact that in order to translate the CR in preliminary layouts of a product, small modules (chunks) needed to be generated, as this will allow for more efficient assigning of the design tasks.

In this regards, Otto and Wood (2001) summarised a four stage process for generating architecture as follows:

Stage 1: Creation of a Function Structure

This stage has been described in section 2.5; moreover, it is considered a major stage as it defines the final product through the main functions and its derived sub functions.

Stage 2: Sub-Functions Clustering

In this stage, the sub-functions are grouped into “chunks” based on the sub-functions dependency on each other, which are then transformed to modules within the product.

Stage 3: Rough Geometric Layout Creation

Based on the selected “chunks” a rough geometrical layout can be generated known as a block diagram.

Moreover, this stage is composed of two sub-stages;

1. Creation of product architecture hierarchy from the chunks of the function structure. This process is illustrated for the example of a printer in Figure 2-27.

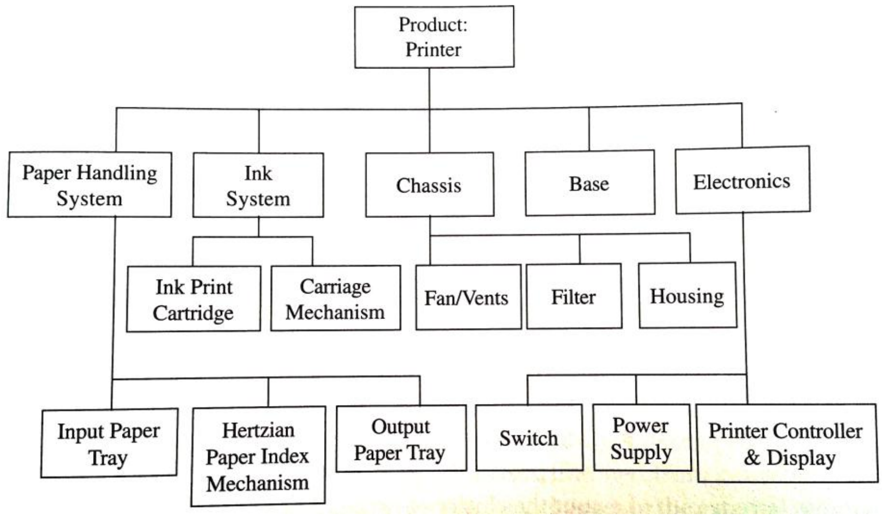


Figure 2-27 Printer component hierarchy (Otto and Wood, 2001)

2. Translation to 2D or 3D sketches of the product layout as illustrated in Figure 2-28.

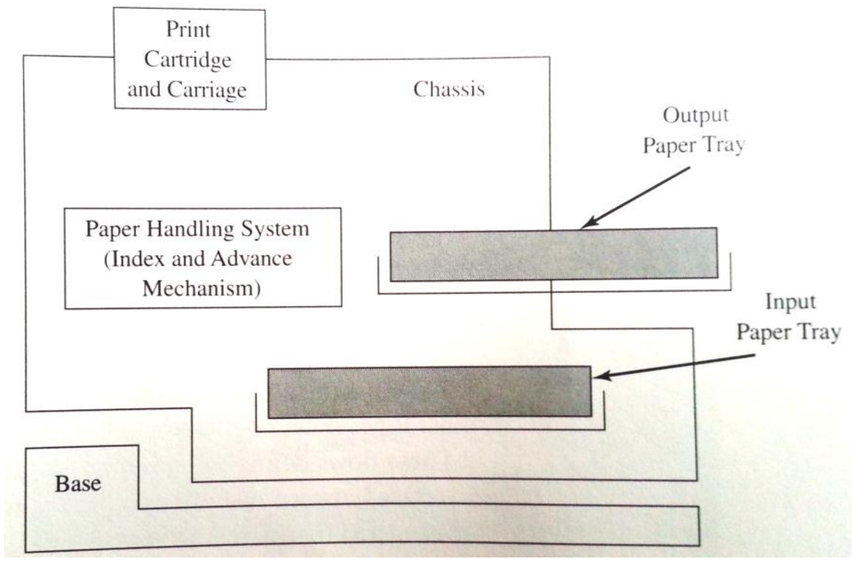


Figure 2-28 Printer geometrical layout

Stage 4: Interaction Definition

In this stage, interactions between the modules need to be defined. Moreover, in order to define these interactions, energy, materials, and signal flows need to be examined and developed (Otto and Wood, 2001).

In addition, Pimmler and Eppinger (1994) proposed an extra basic interaction that relates to physical space and alignment, called spatial (and also known as physical).

Yildirim and Campean (2013) discussed the fact that the definition process for the four types of interactions can be achieved using the interface analysis method that consists of the Interface Matrix (IM) tool. Moreover, they indicated that this tool is commonly used in the automotive industry for supporting the engineering systems design analysis.

Interface Analysis

Interface analysis is designed to identify and characterise all interfaces between subsystems in a systematic way, both in internal and external system boundaries (Yildirim and Campean, 2013).

As an illustration of this type of analysis, Yildirim and Campean (2013) analysed an electric vehicle powertrain (EVP), in the following steps:

The first step was to identify the main functions of the system; and then, to generate a boundary diagram in order to identify the system inputs and outputs, as shown in Figure 2-29.

Inside the system boundary are the subsystems and parts that accomplish the system function, with the external systems located outside. In this figure the arrows indicate the flow direction within the system of the energy, information, and materials.

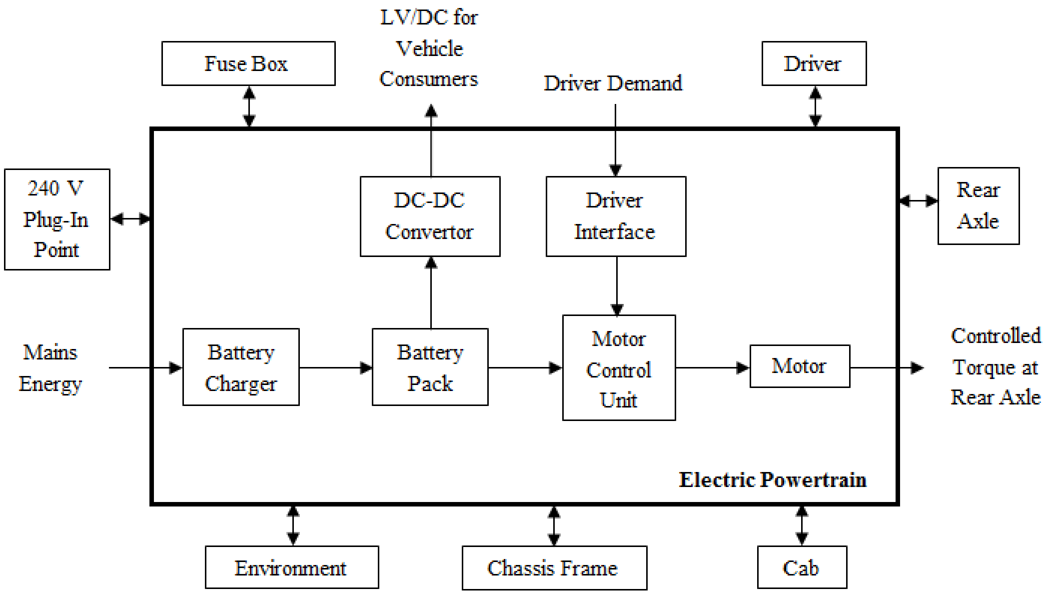


Figure 2-29 System boundary diagram

The third step involves generating the Interface Matrix (IM) in order to document the interface analysis as shown in Figure 2-30; where the cells document the interface existence amongst two subsystems in terms of Physical (P), Energy (E), Information (I), and Material (M) as exchange type.

INTERFACE MATRIX		INTERNAL INTERFACES												EXTERNAL INTERFACES													
		A		B		C		D		E		F		E1		E2		E3		E4		E5		E6		E7	
		Battery Charger		Battery Pack		Driver Interface		Motor Control Unit		Motor		DC-DC Converter		Driver		240 V PIP		Cab		Environment		Chassis Frame		Rear Axle		Fuse Box	
1	Battery Charger				E									P	E	P	E				E	P	E				
				I		I								I							M						
2	Battery Pack		E						E				E	P						P	E	P	E				
		I												I							M		M				
3	Driver Interface													P	E			P	E	P	E						
		I						I				I		I				I			M						
4	Motor Control Unit				E						E									P	E	P	E				
						I				I											M						
5	Motor								E											P	E	P	E	P	E		
								I													M				M		
6	DC-DC Converter				E															P	E					P	E
						I																					

Figure 2-30 Interface matrix (IM)

Finally, once the type of exchange at the interface has been identified, the final step is to specify a functional requirement in order to manage it (Yildirim and Campean, 2013).

2.7 Summary

The advantages and disadvantages associated with various product development tools and methodologies have been discussed in this chapter. By understanding the characteristics of each tool, the study managed to select, modify and efficiently deploy number of tools such as the AHP, Kano, and QFD to establish a concept for a system under consideration. .

Similarly, understanding their limitations allowed this study to verify the outcome by using two separate and independent tools such as Kano and AHP. Having understood the QFD limitations when dealing with large set of CRs led to the development of the dual mode QFD, which consist of two smaller in size QFD matrices that are overlaid on each other. This led to realistic and verifiable target values. Moreover this approach resulted in enhanced capability to deal with larger set off CRs in smaller and manageable QFD matrix.

3 IMPLEMENTATION

3.1 Chapter Roadmap

This chapter utilises the selected product development methodologies and tools described in the previous chapter and applies it to a real life example to enhance and improve its performance by firstly focusing on critical requirements which generate high level of satisfaction and delight and secondly specifying realistic performance targets to ensure improved performance and overall customer satisfaction.

The following sections are structured to introduce the two main phases of the general product development process, namely, “understand the opportunity” and “development of a concept” phases, with a workflow starting from capturing and analysing the CRs, then transforming them into target values and functions. Finally it generates a preliminary architecture and interface analysis.

The preliminary results generated by the end of each section are detailed in the next chapter. This is to avoid any confusion or mix-up between analysing the implementation process and utilising the implementation process to obtain the results. For clarity, results are covered section by section to assist with the flow and understanding.

3.2 Methodology

Based on the problem statement, and project aims, there was a growing need to focus more on the customer requirements in order to improve the customer satisfaction level in the next generation MATV.

In this regard, while searching for the suitable tools and methodologies, it was noted that when trying to address a large number of customer requirements, the available tools -such as the QFD- suffered from an excessive table size or matrices, leading to an unnecessary complexity during their handling, processing and analysis utilisation.

In order to overcome such a problem, the study worked on a new methodology that concentrates on decomposing the user requirements into smaller groups, then analysing them in parallel, and finally overlying the results to select the most significant values, almost in the same manner as the computer CPU when dealing the input data.

More specifically, as a first step in the new methodology, the user requirements were decomposed and identified into their main elements including; basic, one dimensional and attractive requirement, moreover, in this study, two groups of CRs were generated, the basic oriented group, consisting mainly of basic and one-dimensional requirements, and the attractive oriented group.

This action, has allowed concentrating on a smaller size of CRs based on their type, also to select the most suitable prioritisation and ranking tool for the next step such as the Kano model for analysing attractive oriented CRs.

Once the two CRs groups have been prioritised, the overall CRs number can be reduced by selecting the highly ranked items by the customers, as a result, the next step will be significantly simplified due to the reduced size of input CRs.

The next step mainly concerned with correlating the selected CRs with the product parameters\functional requirements, in order to achieve target values\product specifications. For that, the QFD process was selected due to its solid capability in performing such analysis, however, having the reduced size of CRs, the QFD has become feasible to analyse them, with a relatively a manageable size of its matrix.

The QFD size was got even smaller- hence simpler, efficient, and more accurate- by the introduction of a new approach called “Dual Mode QFD”. This technique consists of two smaller QFDs analysing a separate group of CRs, and then overlaid on each other to select the most significant target values. More details about this process are covered in section 3.3.2.1.

The advantage of this approach is clearly marked by the added verification of the selected target values\specifications, also by the downsized QFDs which make them simple and more manageable to use. Additionally, the approach benefited from the utilisation of the “Design Drivers” technique to select the FRs with the QFD in a logical and systematic way.

The product development steps continues by performing a comprehensive functional analysis using the function hierarchy technique for decomposing the high-level CRs to generate the basic functions which describe the design actions and technologies needed to achieve the product target values\specifications

Finally, due to the time limitation within this study, the product development progress halts at the architectural analysis stage, where the basic functions were correlated with the product physical components to generate product architecture, and an interface analysis performed to the product systems and components.

For more insight, the following list give further explanation and discussion on the tools and methodologies selected and implemented by the study.

- **The Analytic Hierarchy Process (AHP)**; this tool has been a major implement at the hands of decision makers and researchers to enable them to establish the priority of customer needs based on the multiple principles decision-making technique.

  In the study, a partial implementation of this tool was carried out on the basic and mandatory requirements, in order to be compatible with the nature of the generated user requirements hierarchy (Hierarchy I).

- **Kano Model;** this is a valuable tool for understanding customer needs and their influence on customer satisfaction. In this regard, this tool was used to elect the attractive-oriented customer requirements (CRs) within (Hierarchy II).

- **QFD;** this was developed as a very powerful tool that translates the voice of the customer into technical or design specifications. Moreover, within this study, this tool was the basis for development of the “Integrated Dual Mode QFD”.

- **Integrated Dual Mode QFD;** This unique tool has been developed to focus more on the classification of customer needs in terms of basic, performance, and attractive requirements. The technique consists of two overlaid QFDs (AHP-based and Kano-based QFDs) with common functional requirements.

  This modified QFD allows for selection of the best target values that fulfil a wider spectrum of customer requirements in a relatively simple and manageable size QFD.

- **Design Drivers;** this method is used as a primary decision making process, however, in this study, it was – for the first time – linked with the QFD, through the transfer of CRs into FRs for the FR section within the QFD.

- **Function Hierarchy;** this is one of the basic techniques used in the functional modelling phase, as the hierarchy of functions is generated by starting with the high-level function of the product as a hierarchy core, and then decomposed into basic functions.

- **Architectural Analysis:** this analysis was undertaken to analyse the arrangement and interfaces of various sub-systems to allow compact and efficient product layout.

- **Interface Matrix (IM);** this is a commonly used tool in the automotive industry for supporting the engineering systems design analysis. For this study, it helped in defining the interfaces between subsystems of the MATV.

3.3 Understand the Opportunity Phase

This study has focused on the customer need and competitive analysis only. Essentially, it is assumed that the outcome of the first two actions are already established – namely as outlined earlier, the development of a second generation militarised all-terrain vehicle (MATV).

In order to accomplish this phase, a new approach was achieved here by developing an integrated dual mode Quality Function Deployment (QFD) analysis. The dual mode QFD consists of two QFDs with common functional (engineering) requirements, and different customer requirements (CRs) of the same product. The priorities for the user requirements were derived by utilising the Analytical Hierarchy Process (AHP) for the first mode, while the second mode employs the Kano model method to select and prioritise the CRs.

The main objective behind the development of a dual mode QFD was due to its capability of compiling a larger spectrum of CRs, ranging from basic to attractive needs, with a relatively smaller and hence more manageable QFD matrix. The dual mode QFD process was used to select the best target values out of the two QFDs. In short, this approach overcame any personal likeness or preference towards a requirement, and acted as a counter check by offering a balanced view.

3.3.1 Customer Need Analysis and Prioritisation

This stage is considered a preparation for the competitive analysis stage, during which, the CRs inputs for both QFD modes are structured, prioritised and selected.

The main actions starts with structuring the CRs within two hierarchies, Hierarchy I, which is more oriented toward the basic needs, and Hierarchy II which more biased to attractive needs. Later on, the CRs within each hierarchy are analysed and prioritised using the AHP for (Hierarchy I) and Kano method for (Hierarchy II).

3.3.1.1 Requirements Structuring

The main aim of designing and drafting a questionnaire is to clearly, accurately and in a concise manner, tease out customer voices using short and precise statements. Consequently, the number of requirements to be investigated has to be minimised, while still covering the entire spectrum of product (here MATV) specifications.

For this study, two hierarchies with two levels of product specifications were generated, including level I, level II-A, and level II-B. These generated specifications have been interpreted as requirements within the VOC questionnaires used in later stages. Moreover, as part of this stage, a divergent type hierarchical structure (Leighton et al., 2004) has been organised due to its capability of covering larger spectrum of sub-requirements at lower levels. Therefore, this involved starting a high level set of basic attributes/requirements (level I) for both hierarchies, which were then further decomposed into a set of lower level detailed requirements in both hierarchy I (level II-A) and in hierarchy II (level II-B), as shown in Figure 3-1, and Figure 3-2 respectively.

Furthermore, the reason behind having two hierarchies with sub levels ‘A’ and ‘B’, is to have a preliminary separation between the basic and mandatory requirements (A), and the attractive or reversal requirements (B) (Wang and Ji, 2010). Moreover, this separation will lead to a more compatible hierarchy of requirements (hierarchy I) which is needed to setup the Analytical Hierarchy Process (AHP) questionnaire in the next phase; similarly, the hierarchy II is more oriented to suit a Kano questionnaire type.

From both the top level and the subsequently decomposed requirements established in both Hierarchy I and Hierarchy II were derived from common practice knowledge in the automotive industry. Nevertheless majority of the requirements were established from the lessons learned during the development of the 1st generation MATV.

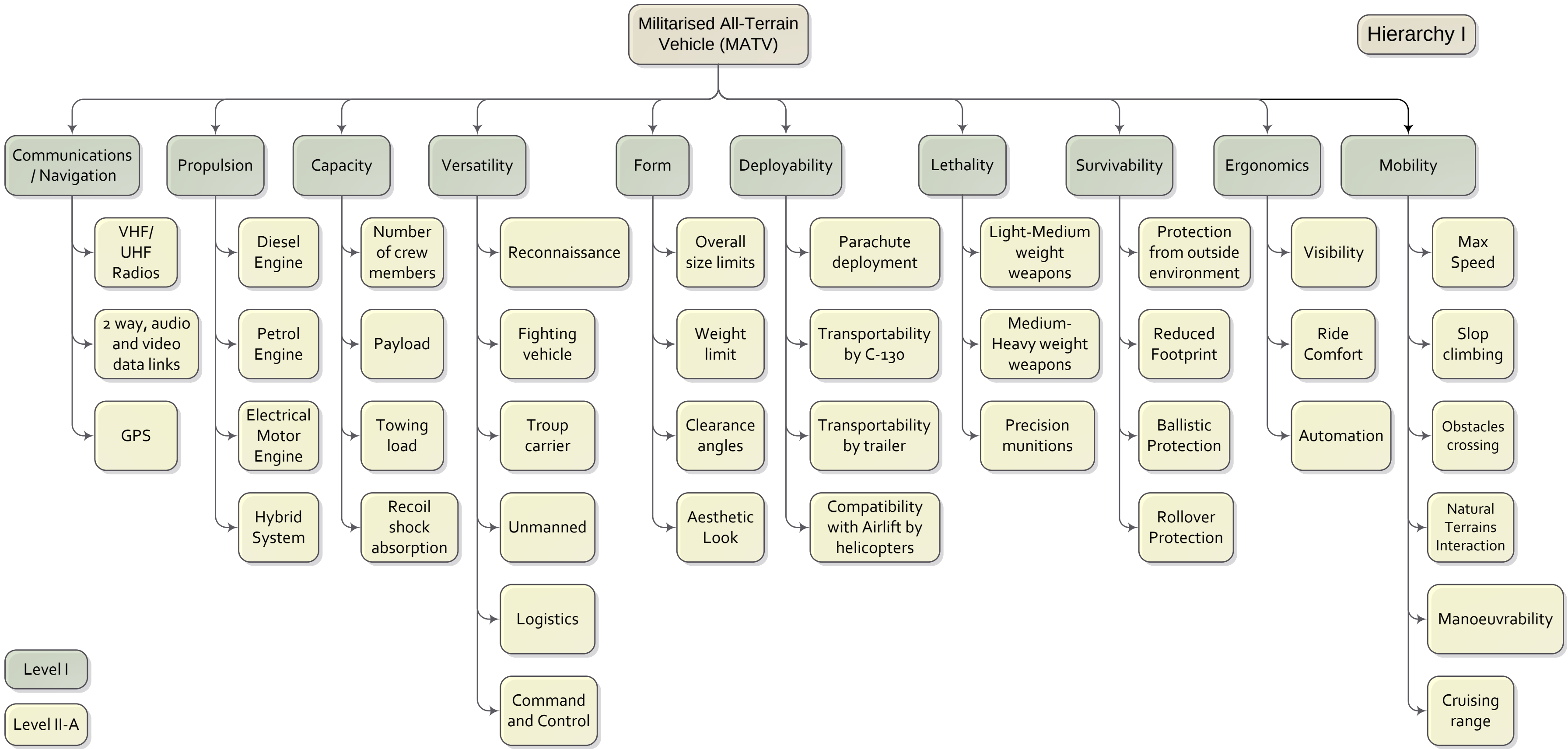


Figure 3-1 User requirements hierarchy I

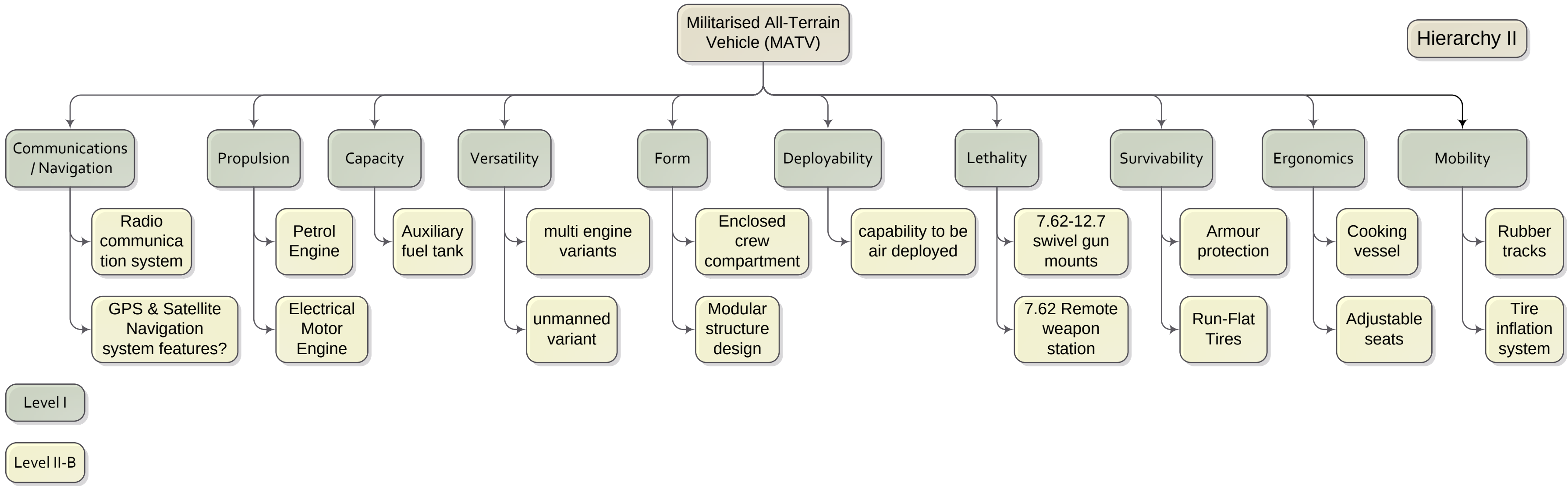


Figure 3-2 User requirements hierarchy II

1. Level I Requirements:

This is a common level between Hierarchy I and Hierarchy II; it consists of the general attributes for describing common land vehicles, which can be used to describe the MATV in this research. To this end, ten attributes were defined as shown in Table 3-1.

Table 3-1 Level I requirements

level	Description	level	Description
1.1	Mobility	**1.6**	Form
1.2	Ergonomics	**1.7**	Versatility
1.3	Survivability	**1.8**	Capacity
1.4	Lethality	**1.9**	Propulsion
1.5	Deployability	**1.10**	Communications/Navigation

2. Level II Requirements:

In this stage, based on expert judgment and historical needs/requirements for the previous generation MATV, level I was further decomposed in to 41 general sub-requirements within level II-A resembling the systems (relatively) basic needs. Similarly, level I was once again decomposed to a set of 18 general sub-requirements within level II-B, in this case with these sub-requirements resembling relatively attractive needs, as shown in Tables 3-2 to 3-11.

Table 3-2 Level II, mobility

<table>
<tr><th>level I</th><th>Description</th><th>Level II-A</th><th>Description</th><th></th><th>Level II-B</th><th>Description</th></tr>
<tr><td rowspan="6">1.1</td><td rowspan="6">Mobility</td><td>2.1a</td><td>Max Speed</td><td rowspan="6"></td><td rowspan="3">2.1b</td><td rowspan="3">Rubber tracks</td></tr>
<tr><td>2.2a</td><td>Slop climbing</td></tr>
<tr><td>2.3a</td><td>Obstacles crossing</td></tr>
<tr><td>2.4a</td><td>Natural Terrains Interaction</td><td rowspan="3">2.2b</td><td rowspan="3">Tyre inflation system</td></tr>
<tr><td>2.5a</td><td>Manoeuvrability</td></tr>
<tr><td>2.6a</td><td>Cruising range</td></tr>
</table>

Table 3-3 Level II, ergonomics

level I	Description	Level II-A	Description		Level II-B	Description
1.2	**Ergonomics**	2.7a	Visibility		2.3	Cooking vessel
		2.8a	Ride Comfort		2.4	Adjustable seats
		2.9a	Automation			

Table 3-4 Level II, survivability

level I	Description	Level II-A	Description		Level II-B	Description
1.3	**Survivability**	2.10a	Protection from outside environment		2.5b	Armour protection
		2.11a	Reduced Footprint			
		2.12a	Ballistic Protection		2.6b	Run-Flat Tires
		2.13a	Rollover Protection			

Table 3-5 Level II, lethality

level I	Description	Level II-A	Description		Level II-B	Description
1.4	**Lethality**	2.14a	Light-Medium weight weapons		2.7b	7.62-12.7 swivel gun mounts
		2.15a	Medium-Heavy weight weapons		2.8b	7.62 Remote weapon station
		2.16a	Precision munitions			

Table 3-6 Level II, deployability

level I	Description	Level II-A	Description		Level II-B	Description
1.5	**Deployability**	2.17a	Parachute deployment		2.9b	Capability to be air deployed
		2.18a	Transportability by C-130			
		2.19a	Transportability by trailer			
		2.20a	Compatibility with Airlift by helicopters			

Table 3-7 Level II, form

level I	Description	Level II-A	Description		Level II-B	Description
1.6	**Form**	2.21a	Overall size limits		2.10b	Enclosed crew compartment
		2.22a	Weight limit			
		2.23a	Clearance angles		2.11b	Modular structure design
		2.24a	Aesthetic Look			

Table 3-8 Level II, versatility

level I	Description	Level II-A	Description		Level II-B	Description
1.7	Versatility	2.25a	Reconnaissance		2.12b	multi engine variants
		2.26a	Fighting vehicle			
		2.27a	Obstacles crossing			
		2.28a	Troup carrier		2.13b	unmanned variant
		2.29a	Unmanned			
		2.30a	Command and Control			

Table 3-9 Level II, capacity

level I	Description	Level II-A	Description		Level II-B	Description
1.8	Capacity	2.31a	Number of crew members		2.14b	Auxiliary fuel tank
		2.32a	Payload			
		2.33a	Towing load			
		2.34a	Recoil shock absorption			

Table 3-10 Level II, propulsion

level I	Description	Level II-A	Description		Level II-B	Description
1.9	Propulsion	2.35a	Diesel Engine		2.15b	Petrol Engine
		2.36a	Petrol Engine			
		2.37a	Electrical Motor Engine		2.16b	Electrical Motor Engine
		2.38a	Hybrid System			

Table 3-11 Level II, communications / navigation

level I	Description	Level II-A	Description		Level III	Description
1.10	Communications / Navigation	2.39a	VHF/ UHF Radios		2.17b	Radio communication system
		2.40a	2 way, audio and video data links		2.18b	GPS & Satellite Navigation system features?
		2.41a	GPS			

3.3.1.2 CR Analysis and Selection - Analytic Hierarchy Process (AHP)

The analytic hierarchy process (AHP) generates a global rating for each requirement (hierarchy I). The global rating for each requirement is then used as a reference for ranking all alternatives with regards to each other.

Essentially, in this analysis the importance of each requirement in comparison with the other is determined through a set of questionnaires. Building on this, the important comparison values for level I and each category within level II-A are arranged in a square matrix form. This approach allows reduction of large data sets via subsequent selection of only those modes with significant global rating for further consideration. Here, the resulting classification has been correlated with the results generated from the Kano model analysis in order to develop the dual mode QFD as discussed earlier in this chapter.

1. Importance Evaluation Questionnaires:

Two questionnaires were developed covering level I and level II-A within the requirements (hierarchy I). For each level, the importance of each need/requirement in comparison with the other has been determined. Two sample questionnaires are shown in Figure 3-3, and Figure 3-4, while full copies for both questionnaire templates (Figure A-1, and Figure A-2) are presented in Appendix A.1.

2. Administering the Customer Questionnaires:

The selected method for ascertaining customer importance weighting with regards to the proposed requirements was distribution of the questionnaires via email, after which the results were gathered and archived for the next stage.

In order to complete this study in 12 months there was a limited time in which questionnaire was drafted and emailed to potential stakeholders. Clearly time limitation did not allowed the author to cover the full spectrum of stakeholders. However, this limitation was addressed by approaching KADDB engineers with design experience, officers with operational and maintenance experience, production and manufacturing experience to overcome some inadequacies of not being able to cover the full customer/stakeholder spectrum. Thus a population of twenty employees from KADDB, acting as customers participated in completing the questionnaires to initiate this study. As we all recognise, design is iterative in nature therefore during the next iteration, wider population will be consulted and interviewed to further refine the results as part of future work. The participants were categorised in to two user groups consisting of military and civilian backgrounds in order to reflect a wider spectrum of future customers.

Further, the two user groups also included senior, junior, technical, and managerial levels in order to provide a more balanced and representative overall view (customer voice).

New Product Development Questionnaire Level I	
Name:	....
Job Title/Function:	....
Date questionnaire completed:	....
Temp. Title:	2nd Generation KADDB Light Tactical 4x4 All-Terrain Vehicle
Questionnaire Description:	The questionnaire will highlight and prioritize the main enhanced characterises (at high level) of the 2nd generation KADDB Light Tactical 4x4 All-Terrain Vehicle. As well-known, the current generation is exclusively designed to meet Jordan Armed Forces defence capabilities. It can be customized to be used as a tactical vehicle for agile forces with fast response actions by transporting in all terrain from 2 up to 4 soldiers of special operation, infantry or as logistic vehicle. The vehicle can also be deployed by land, sea, and air (C130 or Helicopter). (please refer to the back of the questioner for terms explanation)

No.	Question	Answers (circle one choice only)
		Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10
1	How would you rank Mobility against Ergonomics?	1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)
		Importance Level Not ←→ Extremely
2	How would you rank Mobility against Survivability?	1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)
		Importance Level Not ←→ Extremely
3	How would you rank Mobility against Lethality?	1 2 3 4 5 6 7 8 9 10

Figure 3-3 Level I importance evaluation sample questionnaire

New Product Development Questionnaire (Level II-A)		
	Name:	
	Job Title/Function:	
	Date questionnaire completed:	
	Temp. Title:	2nd Generation KADDB Light Tactical 4x4 All-Terrain Vehicle
	Questionnaire Description:	The questionnaire will highlight and prioritize the main Level II-A characterises of the 2nd generation KADDB Light Tactical 4x4 All-Terrain Vehicle.

Mobility

No.	Question	Answers (circle one choice only)
1	How would you rank Max Speed against Slop climbing?	Importance Level: Not ← → Extremely 1 2 3 4 5 6 7 8 9 10
2	How would you rank Max Speed against Obstacles crossing?	Importance Level: Not ← → Extremely 1 2 3 4 5 6 7 8 9 10
3	How would you rank Max Speed against Natural Terrains Interaction?	Importance Level: Not ← → Extremely 1 2 3 4 5 6 7 8 9 10
4	How would you rank Max Speed against Manoeuvrability?	Importance Level: Not ← → Extremely 1 2 3 4 5 6 7 8 9 10
5	How would you rank Max Speed against Cruising range?	Importance Level: Not ← → Extremely 1 2 3 4 5 6 7 8 9 10
6	How would you rank Slop climbing against Obstacles crossing?	Importance Level: Not ← → Extremely 1 2 3 4 5 6 7 8 9 10

Figure 3-4 Level II-A importance evaluation sample questionnaire

3. Data Registration:

The questionnaire results from the 20 participants were averaged and tabulated in Table 3-12 and Table 3-13. For reference, complete tables (Table A-1, and Table A-2) are given in Appendix A.2.

Table 3-12 Level I sample answer table

No.	Question	Avg. Result	Customer 1	Customer 2
1	Mobility vs. Ergonomics	6.95	7	8
2	Mobility vs. Survivability	5.95	5	7
3	Mobility vs. Lethality	6.5	5	5
4	Mobility vs. Deployability	6.5	7	5
5	Mobility vs. Form	6.5	6	8
6	Mobility vs. Versatility	6.4	7	3
7	Mobility vs. Capacity	6.5	6	7
8	Mobility vs. Propulsion	6.3	7	4
9	Mobility vs. Communications / Navigation	6.3	6	4
10	Ergonomics vs. Survivability	4.6	4	4

Table 3-13 Level II-A sample answer table

	No.	Question	Avg. Result	Customer 1	Customer 2
Mobility	1	Max Speed vs. Slop climbing	5.3	6	8
	2	Max Speed vs. Obstacles crossing	5.15	6	5
	3	Max Speed vs. Natural Terrains Interaction	5.5	6	8
	4	Max Speed vs. Manoeuvrability	5.15	5	6
	5	Max Speed vs. Cruising range	5.3	6	8
	6	Slop climbing vs. Obstacles crossing	5.9	5	6
	7	Slop climbing vs. Natural Terrains Interaction	6.3	5	7
	8	Slop climbing vs. Manoeuvrability	5.65	4	5
	9	Slop climbing vs. Cruising range	6.35	5	4
	10	Obstacles crossing vs. Natural Terrains Interaction	6.05	5	8
	11	Obstacles crossing vs. Manoeuvrability	5.75	4	5
	12	Obstacles crossing vs. Cruising range	5.9	6	4
	13	Natural Terrains Interaction vs. Manoeuvrability	5.3	5	7
	14	Natural Terrains Interaction vs. Cruising range	5.6	7	7
	15	Manoeuvrability vs. Cruising range	6.4	7	5

4. Data Processing:

Based on the methodology described in section 2.3.3, the following three stages were performed, including multiple steps for each stage:

First Stage; Criterions Relative Importance: The averaged pairwise comparisons for the 10 (Level I) requirements, described as criterions, were arranged in rows and columns of an n x n matrix. In the second step, normalised average column values were used to estimate the eigenvector of the matrix (Saaty, 1980). For the purpose of this research, a MATLAB® (MathWorks, 2014) code was developed for this calculation as shown in Appendix A.3. Finally, in the third step, each requirement (criterion) was assigned its relative value based on the calculated eigenvector as shown in Table 3-14.

Second Stage; Alternatives Relative Importance: Alternatives are defined as substitute or equivalent second choices to meet the CRs. Their relative importance is obtained in the same way as explained above. Forty-one customer requirements identified as level II-A, and shown in Figure 3-1, were used to obtain the relative importance. The level IIA requirements are described as alternatives in the general AHP hierarchy (Saaty, 1980).

Third Stage; Alternatives Global Importance: Based on partial application of the AHP section 2.3.3.2 , the relative importance/weight for each alternative was multiplied with by the relative importance/weight of its corresponding criterion in order to generate the final global importance/weight.

This process is illustrated for each category in Table 3-15, Table 3-16, and Table 3-17. The remaining set of tables (Table A-3 to Table A-9) can be found in Appendix A.4.

Table 3-14 level I Pairwise comparisons matrix

Level I												
Requrements		R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	Eigenvector
		Mobility	Ergonomics	Survivability	Lethality	Deployability	Form	Versatility	Capacity	Propulsion	Communications / Navigation	
R1	Mobility	1	2.2787	1.4691	1.8571	1.8571	1.8571	1.7778	1.8571	1.7027	1.7027	**0.1651**
R2	Ergonomics	0.4388	1	0.8519	0.8349	1.0202	1.1277	1.1505	1.2222	0.9231	1.1277	**0.0904**
R3	Survivability	0.6807	1.1739	1	1.4096	1.8169	2.3898	2.0303	1.6667	1.3529	1.7397	**0.1397**
R4	Lethality	0.5385	1.1978	0.7094	1	1.4691	1.6316	1.5641	1.2222	1.2727	1.2472	**0.1086**
R5	Deployability	0.5385	0.9802	0.5504	0.6807	1	1.7397	1.5641	1.3810	1.1978	1.1978	**0.0976**
R6	Form	0.5385	0.8868	0.4184	0.6129	0.5748	1	1.0202	0.9231	0.8868	1.0619	**0.0731**
R7	Versatility	0.5625	0.8692	0.4925	0.6393	0.6393	0.9802	1	1	0.9417	0.8692	**0.0746**
R8	Capacity	0.5385	0.8182	0.6000	0.8182	0.7241	1.0833	1	1	1.2222	1.4390	**0.0856**
R9	Propulsion	0.5873	1.0833	0.7391	0.7857	0.8349	1.1277	1.0619	0.8182	1	1.2989	**0.0876**
R10	Communications / Navigation	0.5873	0.8868	0.5748	0.8018	0.8349	0.9417	1.1505	0.6949	0.7699	1	**0.0777**

Table 3-15 Mobility, global importance

Level II-A, Mobility											
Mobility Requrements		R1-1	R1-2	R1-3	R1-4	R1-5	R1-6	Eigenvector (relative importance)	Mobility (relative importance)	Global importance
		Max Speed	Slop climbing	Obstacles crossing	Natural Terrains Interaction	Manoeuvrability	Cruising range			
R1-1	Max Speed	1	1.1277	1.0619	1.2222	1.0619	1.1277	**0.1804**	**0.1651**	**0.02978404**
R1-2	Slop climbing	0.8868	1	1.4390	1.7027	1.2989	1.7397	**0.2136**		**0.03526536**
R1-3	Obstacles crossing	0.9417	0.6949	1	1.5316	1.3529	1.4390	**0.1827**		**0.03016377**
R1-4	Natural Terrains Interaction	0.8182	0.5873	0.6529	1	1.1277	1.2727	**0.1431**		**0.02362581**
R1-5	Manoeuvrability	0.9417	0.7699	0.7391	0.8868	1	1.7778	**0.1597**		**0.02636647**
R1-6	Cruising range	0.8868	0.5748	0.6949	0.7857	0.5625	1	**0.1206**		**0.01991106**

Table 3-16 Ergonomics, global importance

Level II-A, Ergonomics							
Ergonomics Requrements		R2-1	R2-2	R2-3	Eigenvector (relative importance)	Ergonomics (relative importance)	Global importance
		Visibility	Ride Comfort	Automation			
R2-1	Visibility	1	1.2989	1.7397	**0.425**	**0.0904**	**0.03842**
R2-2	Ride Comfort	0.7699	1	1.5000	**0.3398**		**0.03071792**
R2-3	Automation	0.5748	0.6667	1	**0.2352**		**0.02126208**

Table 3-17 Survivability, global importance

Level II-A, Survivability								
Survivability Requrements		R3-1	R3-2	R3-3	R3-4	Eigenvector (relative importance)	Survivability (relative importance)	Global importance
		Protection from outside environment	Reduced Footprint	Ballistic Protection	Rollover Protection			
R3-1	Protection from outside environment	1	1.2472	1.0408	0.8018	**0.2502**	**0.1397**	**0.03495294**
R3-2	Reduced Footprint	0.8018	1	1.2222	0.6949	**0.2264**		**0.03162808**
R3-3	Ballistic Protection	0.9608	0.8182	1	0.8868	**0.2276**		**0.03179572**
R3-4	Rollover Protection	1.2472	1.4390	1.1277	1	**0.2959**		**0.04133723**

3.3.1.3 CR Analysis and Selection-Kano Model

The Kano model mode utilised the hierarchy II (see Figure 3-2) consisting of level II-B requirements; this level constitutes a mixture of attractive and supplementary needs, which were generated during the product lifecycle of the 1st generation MATV. By using the Kano model, these requirements – or needs – were thoroughly classified into basic, one-dimensional, and attractiveness needs and then ranked with the help of the self-stated importance rating.

The classification resulting from this process has been correlated with results generated from the AHP analysis for the development of the dual mode QFD during the concept development phase.

1. Kano Questionnaire

The Kano questionnaire (Violante and Vezzetti, 2013) primarily needed to capture the one-dimensional and attractive requirements. It also needed to identify product requirements towards which the customer is indifferent.

For each product level II-B requirement, a pair of questions has been formulated which the customer can answer in one of five different ways as explained in section 2.3.4. Further, self-stated-importance questions were included as part of the complete Kano questionnaire setup. A sample of the questionnaire highlighting this approach is shown Figure 3-5. In turn, the full questionnaire (Figure B-1) is presented in Appendix B.1.

New Product Development Questionnaire (Level II-B)		
	Name:	....
	Job Title/Function:	....
	Date questionnaire completed:	....

No.	Question	Answers (select with a X one choice only)
1A	If the vehicle has tire inflation system	1. I like it 2. I expect it 3. I'm neutral 4. I can tolerate it 5. I dislike it
No.	**Question**	**Answers (select with a X one choice only)**
1B	If the vehicle doesn't have tire inflation system	1. I like it 2. I expect it 3. I'm neutral 4. I can tolerate it 5. I dislike it
No.	**Question**	**Answers (select with a X one choice only)**
2A	If the vehicle has adjustable seats	1. I like it 2. I expect it 3. I'm neutral 4. I can tolerate it 5. I dislike it
No.	**Question**	**Answers (select with a X one choice only)**
2B	If the vehicle doesn't have adjustable seats	1. I like it 2. I expect it 3. I'm neutral 4. I can tolerate it 5. I dislike it

Figure 3-5 Sample section from the Kano questionnaire

Source: (Violante and Vezzetti, 2013)

2. Administering the Customer Questionnaires

The Kano questionnaire administration process utilised the same approach employed during the AHP phase, including the same population of participants (see section 3.3.1.2), in order to ensure consistency in the results obtained.

3. Data Registration

The questionnaire results were registered in two stages. Initially the answers to the functional and dysfunctional question were combined in the evaluation Table 3-18, while the self-stated importance ratings are summarised in Table 3-19 (a full sized VOC answer table is presented in Table B-1, Appendix B.2). The results of the individual product criteria were listed in Table 3-20 which shows the overall distribution of the requirement categories.

Table 3-18 Kano sample evaluation table

Customer requirements → ↓		Dysfunctional (negative) question				
		1. like	2. must be	3. neutral	4. live with	5. dislike
Functional (positive) question	1. like	Q	A	A	A	O
	2. must-be	R	I	I	I	M
	3. neutral	R	I	I	I	M
	4. live with	R	I	I	I	M
	5. dislike	R	R	R	R	Q

Customer requirement is ...

A: Attractive
M: Must-be
R: Reverse

O: One-dimensional
Q: Questionable
I: Indifferent

Table 3-19 VOC answer table

Questionnaire			Customer 1		Customer 2	
		Name:				
		Company Name:				
		Job Title/Function:				
		Date questionnaire completed:				
		Interviewers name (if applicable):				
No.	**Question**	**Answers (select with a X one choice only)**	**Answers**	**Evaluation**	**Answers**	**Evaluation**
1A	If the vehicle has tire inflation system	1. I like it				
		2. I expect it			X	
		3. I'm neutral	X			
		4. I can tolerate it				
		5. I dislike it				
No.	**Question**	**Answers (select with a X one choice only)**	**Answers**		**Answers**	
1B	If the vehicle doesn't have tire inflation system	1. I like it				
		2. I expect it				
		3. I'm neutral	X			
		4. I can tolerate it				M
		5. I dislike it			X	
No.	**Question**	**Answers (select with a X one choice only)**	**Answers**		**Answers**	
1C	How would you rank the tire inflation system feature?	**Importance Level** **Not** ... **Extremely** **1 2 3 4 5 6 7 8 9 10**	5	I	9	

Table 3-20 Tabulation of questionnaire response (Functional/Dysfunctional)

Customer Requirement Questions			Attractive	One-dimensionsal	Must-be	Indifferent	Reverse	Questionable	Total
Q01	Tire inflation system (Mobi)	Responses	4	3	1	11	1	0	20
		Percentage	20%	15%	5%	55%	5%	0%	100%
Q02	Adjustable seats (Ergo)	Responses	6	1	5	8	0	0	20
		Percentage	30%	5%	25%	40%	0%	0%	100%
Q03	Enclosed crew compartment (Form)	Responses	4	2	0	12	2	0	20
		Percentage	20%	10%	0%	60%	10%	0%	100%
Q04	Multi engine variants (Vers)	Responses	6	1	0	11	2	0	20
		Percentage	30%	5%	0%	55%	10%	0%	100%
Q05	Radio communication system (Comu)	Responses	5	1	3	10	1	0	20
		Percentage	25%	5%	15%	50%	5%	0%	100%
Q06	Run-Flat Tires (Serv)	Responses	7	3	3	5	2	0	20
		Percentage	35%	15%	15%	25%	10%	0%	100%
Q07	GPS & Satellite Navigation system (Comu)	Responses	8	1	1	9	1	0	20
		Percentage	40%	5%	5%	45%	5%	0%	100%
Q08	Armour protection (Serv)	Responses	8	0	1	9	1	1	20
		Percentage	40%	0%	5%	45%	5%	5%	100%
Q09	Cooking vessel (Ergo)	Responses	4	0	1	12	4	0	21
		Percentage	19%	0%	5%	57%	19%	0%	100%
Q10	7.62-12.7 swivel gun mounts (Leth)	Responses	8	1	2	9	0	0	20
		Percentage	40%	5%	10%	45%	0%	0%	100%
Q11	7.62 Remote weapon station (Leth)	Responses	9	1	0	9	1	0	20
		Percentage	45%	5%	0%	45%	5%	0%	100%
Q12	Unmanned variant (Vers)	Responses	8	0	0	8	4	0	20
		Percentage	40%	0%	0%	40%	20%	0%	100%
Q13	Auxiliary fuel tank (Caps)	Responses	11	1	1	7	0	0	20
		Percentage	55%	5%	5%	35%	0%	0%	100%
Q14	Petrol engine (Prop)	Responses	3	0	0	11	5	1	20
		Percentage	15%	0%	0%	55%	25%	5%	100%
Q15	Electrical motor engine (Prop)	Responses	3	1	0	8	8	0	20
		Percentage	15%	5%	0%	40%	40%	0%	100%
Q16	Capability to be air deployed (Depl)	Responses	11	3	2	3	1	0	20
		Percentage	55%	15%	10%	15%	5%	0%	100%
Q17	Capability to be fitted with tracks (Mobi)	Responses	5	3	1	9	2	0	20
		Percentage	25%	15%	5%	45%	10%	0%	100%
Q18	Modular structure design (Form)	Responses	7	2	1	8	2	0	20
		Percentage	35%	10%	5%	40%	10%	0%	100%

4. Customer Satisfaction Coefficient (CS Coefficient)

The data from the questionnaire was processed using CS-coefficient equations **(2-3)** and **(2-4).** The results are tabulated in Table 3-21. The CS coefficient diagram as shown in section 4.2.1.2 was then developed using these results.

Table 3-21 ***CS coefficient***

Question No.	Product Requirements	$\frac{A+O}{A+O+M+I}$	$\frac{O+M}{A+O+M+I}$
Q01	Tire inflation system	0.37	-0.21
Q02	Adjustable seats	0.35	-0.30
Q03	Enclosed crew compartment	0.33	-0.11
Q04	Multi engine variants	0.39	-0.06
Q05	Radio communication system	0.32	-0.21
Q06	Run-Flat Tires	0.56	-0.33
Q07	GPS & Satellite Navigation system	0.47	-0.11
Q08	Armour protection	0.44	-0.06
Q09	Cooking vessel	0.24	-0.06
Q10	7.62-12.7 swivel gun mounts	0.45	-0.15
Q11	7.62 Remote weapon station	0.53	-0.05
Q12	Unmanned variant	0.50	0.00
Q13	Auxiliary fuel tank	0.60	-0.10
Q14	Petrol engine	0.21	0.00
Q15	Electrical motor engine	0.33	-0.08
Q16	Capability to be air deployed	0.74	-0.26
Q17	Capability to be fitted with tracks	0.44	-0.22
Q18	Modular structure design	0.50	-0.17

5. Self-Stated Importance

The self-stated importance ratings, gathered via questionnaire (tabulated in Table 3-19, with the full sized VOC answer table presented in Table B-1, Appendix B.2), are set out in Table 3-22. These were then correlated with CS coefficients for the down selection process as discussed in section 4.2.1.2.

Table 3-22 Self-stated importance ranking

Question No.	Requirements	Self-Stated Importance Ranking
Q01	Tire inflation system	6.5
Q02	Adjustable seats	7.1
Q03	Enclosed crew compartment	5.6
Q04	Multi engine variants	5.9
Q05	Radio communication system	6.0
Q06	Run-Flat Tires	7.4
Q07	GPS & Satellite Navigation system	6.3
Q08	Armour protection	5.7
Q09	Cooking vessel	4.2
Q10	7.62-12.7 swivel gun mounts	6.2
Q11	7.62 Remote weapon station	5.1
Q12	Unmanned variant	4.7
Q13	Auxiliary fuel tank	6.9
Q14	Petrol engine	5.5
Q15	Electrical motor engine	4.2
Q16	Capability to be air deployed	7.3
Q17	Capability to be fitted with tracks	5.3
Q18	Modular structure design	5.8

3.3.2 Competitive Analysis

An integrated dual mode QFD analysis was performed in order to define the functionalities and features of the vehicle that best satisfies the customer needs. This analysis also has the advantage that it will help define how the vehicle will compete in the market.

The functional requirements along with the target values were subsequently generated, defining the main engineering specifications of the MATV vehicle. To achieve this, a new approach has been developed that involves utilising the design driver technique to define the basic functional requirements as an input to the QFD technique. This approach has the advantage of applying systematic steps and logical justification to the generated functional requirements, giving greater credibility and applicability to the target values subsequently generated by the QFD method.

3.3.2.1 Integrated Dual Mode QFD

In order to fully represent and correlate the customer needs with the key characterises of the MATV product, the QFD method is used in this research, as it is considered a very powerful tool that integrates the voice of the customer in the designs (Jaiswal, 2012).

In particular, the unique dual mode QFD analysis has focus more on customer needs based on their classification in terms of basic, performance, and attractive requirements.

The first mode employed is called AHP based QFD, whereas the second mode is called Kano based QFD. Both modes share the same functional requirements as a common reference for comparison purposes. This allows determination and selection of the highest target values between both QFDs. As a result, the selected target values will by definition fully cover the three main types of customer needs as mentioned above. This is considered a novel concept compared with the current traditional single mode QFD approaches.

1. House of Quality

Being the first step in the development of the QFD (Hauser and Clausing, 1988), the House of Quality tool consists of a number of stages that must be accomplished before compiling the complete House of Quality layout.

Moreover, for the integrated dual mode approach, two Houses of Quality have been generated; the first utilising user requirements input from the AHP, thus the term “AHP based QFD” was introduced. Likewise, the “Kano based QFD” relied on the Kano method for its input information.

In the following stages, the construction of both modes have been described simultaneously, whereas the processes of overlaying each on the other to allow extraction of the final target vales, is described in the results section.

In addition, the design driver method has been performed during the functional requirements stage, in its role as the main tool for achieving this stage.

Stage 1. Customer Requirements

The results generated by the AHP and Kano models were used to list the top requirements for the QFD analysis.

Of the 41 requirements evaluated in the AHP model, the top 25 highest rated one-dimensional and/or basic needs were used for the QFD analysis. This activity is taken as the first stage of the AHP-based QFD as shown in Table 3-23.

The maximum relationship value represents a (1 or 3 or 9) quantification value of the relationship between the customer and technical requirements. In this context, a value of 1 represents a weak relationship, whereas 3 represent a moderate relationship, and finally, 9 represents a strong relationship.

Furthermore, the customer requirements ratings which were processed in both the AHP and Kano methods are translated into relative weights as shown in Table 3-23 and Table 3-24 respectively.

Table 3-23 AHP-based customer requirements

Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Quality Characteristics (a.k.a. "Functional Requirements" or "How s") / Demanded Quality (a.k.a. "Customer Requirements" or "Whats")
1	9	3.9	3.0	Max speed
2	9	4.7	3.5	Slop climbing
3	9	4.0	3.0	Obstacles crossing
4	9	3.1	2.4	Natural Terrains Interaction
5	9	3.5	2.6	Manoeuvrability
6	9	3.4	2.5	Medium-Heavy w eight w eapons
7	9	5.1	3.8	Visibility
8	9	4.1	3.1	Ride Comfort
9	9	4.6	3.5	Protection from outside environment
10	9	4.2	3.2	Reduced Footprint
11	9	4.2	3.2	Ballistic Protection
12	9	5.5	4.1	Rollover Protection
13	9	6.4	4.9	Light-Medium w eight w eapons
14	9	4.6	3.5	Precision munitions
15	9	3.6	2.8	Parachute deployment
16	9	3.2	2.4	Transportability by C-130
17	9	3.0	2.3	Transportability by trailer
18	9	3.0	2.3	Compatibility w ith Airlift by helicopters
19	9	3.2	2.4	Overall size limits
20	9	3.4	2.6	VHF/ UHF Radios
21	9	3.3	2.5	GPS
22	9	3.5	2.6	Number of crew members
23	9	3.9	2.9	Payload
24	9	5.3	4.0	Diesel Engine
25	9	3.5	2.7	2 w ay, audio and video data

Regarding the Kano mode, the input requirements represent the highest rated 10 out of 24 attractive/one-dimensional needs. This input established the first stage of the Kano based QFD as shown in Table 3-24.

Table 3-24 Kano-based customer requirements

Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Quality Characteristics (a.k.a. "Functional Requirements" or "Hows") / Demanded Quality (a.k.a. "Customer Requirements" or "Whats")
1	9	11.7	7.4	Run-Flat Tires
2	9	11.6	7.3	Capability to be air deployed
3	9	10.9	6.9	Auxiliary fuel tank
4	9	11.3	7.1	Adjustable seats
5	9	10.3	6.5	Tire inflation system
6	9	9.9	6.3	GPS & Satellite Navigation system
7	9	9.7	6.2	7.62-12.7 swivel gun mounts
8	9	9.2	5.8	Modular structure design
9	9	8.1	5.1	7.62 Remote weapon station
10	9	7.4	4.7	Unmanned variant

Stage 2. Rating of the Competition Stage

In this stage of the QFD process, the 1st generation MATV along with other competitors were compared against the new proposed design. The aim of this approach was to allow for a better visualisation of the improvements to be made in the new MATV; this comparison is usually done by asking customers to compare the in-house product with the competitor. However, due to commercial and proprietary reasons, it was difficult for the participating customers within this case study to acquire the detailed specifications of most of the competitors. Consequently, as an alternative approach, and for more reliable results, a quantitative comparison analysis was performed as shown in Table 3-25 and Table 3-26 for the AHP and Kano approaches respectively.

Table 3-25 AHP-based requirements, quantitative comparison analysis

AHP Based Requirements	**Our Company : 2nd Gen. ATV II**		Competitor 1 : 1st Gen. ATV I		Competitor 2: Polaris MRZR 2		Competitor 3: TOMCAR TM5		Competitor 4: JOHN DEERE M-Gator A2	
	Value	**Ranking**	Value	Ranking	Value	Ranking	Value	Ranking	Value	Ranking
Max speed (Km\h)	**75**	**3**	50	2	96	5	86	4	51	2
Slop climbing	**75%front-65% side**	**4**	60%front-40% side	4	60%front-40% side	4	60%front-40% side	4	60%front-40% side	4
Obstacles crossing	**High**	**5**	Medium-High	4	Medium-High	4	Medium-High	4	Medium	3
Natural Terrains Interaction	**High**	**5**	Medium-High	4	Medium-High	4	Medium-High	4	Medium	3
Manoeuvrability	**High**	**5**	Medium-High	4	Medium-High	4	Medium-High	4	Medium	3
Medium-Heavy weight weapons	**Y**	**4**	Y	3	N	0	N	0	N	0
Visibility	**Y**	**4**	Y	4	Y	4	Y	4	Y	4
Ride Comfort	**Y**	**3**	Y	3	Y	3	Y	3	Y	3
Protection from outside environment	**Y**	**4**	N	1	N	1	Y	4	Y	5
Reduced Footprint	**Y**	**3**	N	1	N	2	N	2	N	2
Ballistic Protection	**Y**	**3**	Y	3	N	0	Y	4	N	0
Rollover Protection	**Y**	**4**	Y	4	Y	4	Y	4	Y	4
Light-Medium weight weapons	**Y**	**4**	Y	4	Y	4	Y	4	Y	4
Precision munitions	**Y**	**5**	Y	4	N	2	N	2	N	0
Parachute deployment	**Y**	**4**	N	0	Y	4	Y	3	N	0
Transportability by C-130	**Y**	**4**	Y	3	Y	4	Y	4	Y	3
Transportability by trailer	**Y**	**5**	Y	4	Y	5	Y	5	Y	4
Compatibility with Airlift by helicopters	**Y**	**5**	N	2	Y	5	Y	5	Y	3
Overall size limits (L,W,H)	**3350, 1750, 1800**	**4**	3200, 1730, 1800	3	2931, 1524, 1870	3	3410, 1780, 1690	3	3020, 1571, 1903	3
VHF/ UHF Radios	**Y**	**4**	N	0	Y	4	Y	4	N	0
GPS	**Y**	**4**	Y	4	Y	4	Y	4	Y	4
Number of crew members	**2**	**4**	2	4	2	4	2	4	2	4
Payload Kg	**500**	**4**	250	2	454	3	545	4	635	5
Diesel Engine	**Y**	**4**	Y	4	Y	4	Y	4	Y	4
2 way, audio and video data Com.	**Y**	**3**	N	0	Y	3	Y	3	Y	3

Table 3-26 KANO based requirements, quantitative comparison analysis

KANO Based Requirements	Our Company : 2nd Gen. MATV II		Competitor 1 : 1st Gen. MATV I		Competitor 2: Polaris MRZR 2		Competitor 3: TOMCAR TM5		Competitor 4: JOHN DEERE M-Gator A2	
	Value	**Ranking**	Value	Ranking	Value	Ranking	Value	Ranking	Value	Ranking
Run-Flat Tires	**Y**	**4**	N	2	Y	5	Y	5	N	2
Capability to be air deployed	**Y**	**4**	N	1	Y	5	Y	4	Y	3
Auxiliary fuel tank	**Y**	**5**	N	0	N	2	N	2	N	2
Adjustable seats	**Y**	**5**	N	0	N	1	N	1	N	1
Tire inflation system	**Y**	**5**	N	0	N	1	N	1	N	1
GPS & Satellite Navigation system	**Y**	**4**	N	0	Y	4	Y	4	N	2
7.62-12.7 swivel gun mounts	**Y**	**4**	Y	3	Y	4	Y	4	Y	4
Modular structure design	**Y**	**5**	N	2	N	3	Y	3	N	2
7.62 Remote weapon station	**Y**	**5**	N	2	N	2	N	2	N	2
Unmanned variant	**Y**	**4**	N	0	Y	5	Y	5	N	2

By utilising both AHP and Kano based quantitative comparisons, the following tables/graphs as shown in Table 3-27 and Table 3-28were obtained for AHP and KANO based models respectively.

Table 3-27 AHP based QFD, rating of the competition

Competitive Analysis
(0=Worst, 5=Best)

Our Company : 2nd Gen. ATV II	Competitor 1 :1st Gen. ATV I	Competitor 2: Polaris MRZR 2	Competitor 3: TOMCAR TM5	Competitor 4: JOHN DEERE M-Gator A2
3	2	5	4	2
4	4	4	4	4
5	4	4	4	3
5	4	4	4	3
5	4	4	4	3
4	3	0	0	0
4	4	4	4	4
3	3	3	3	3
4	1	1	4	5
3	1	2	2	2
3	3	0	4	0
4	4	4	4	4
4	4	4	4	4
5	4	2	2	0
4	0	4	3	0
4	3	4	4	3
5	4	5	5	4
5	2	5	5	3
4	3	3	3	3
4	0	4	4	0
4	4	4	4	4
4	4	4	4	4
4	2	3	4	5
4	4	4	4	4
3	0	3	3	3

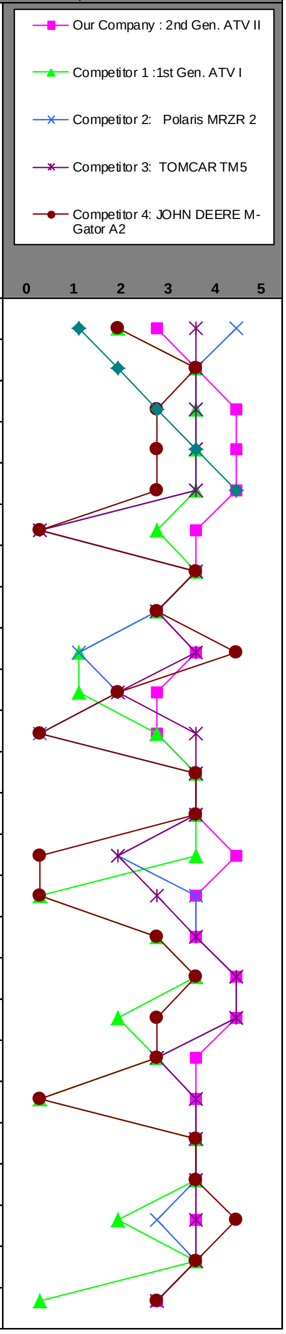
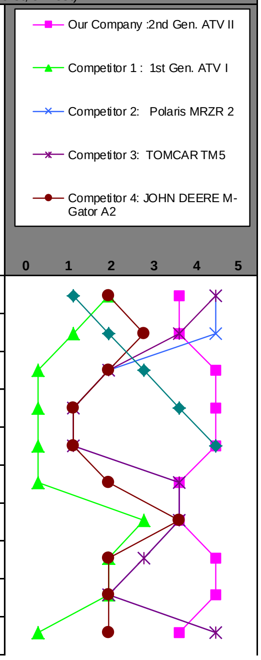


Table 3-28 Kano based QFD, rating of the competition

Competitive Analysis (0=Worst, 5=Best)				
Our Company :2nd Gen. ATV II	Competitor 1 : 1st Gen. ATV I	Competitor 2: Polaris MRZR 2	Competitor 3: TOMCAR TM5	Competitor 4: JOHN DEERE M-Gator A2
4	2	5	5	2
4	1	5	4	3
5	0	2	2	2
5	0	1	1	1
5	0	1	1	1
4	0	4	4	2
4	3	4	4	4
5	2	3	3	2
5	2	2	2	2
4	0	5	5	2



Stage 3. Functional Requirements (FRs)

The functional requirements (FR) represent attributes of the MATV product that can be measured and benchmarked against the competition. Furthermore these requirements are considered the “Hows” for meeting customer needs.

In this study, the FRs are generated through implementation of the Design Drivers technique, in which the selected level I CRs are transferred to FRs. As outlined previously, in this stage both modes (AHP and Kano based QFDs) share the same functional requirements. Moreover, it is worthwhile mentioning, that this is a pioneering implementation of this tool in such an application.

- **Design Drivers:** In order to ensure that the generated FRs fully cover the CRs, level-I CRs were used to generate 10 design driver layouts as shown in Figure 3-6 and in Figure 3-7 with the remaining set of design drives layouts presented in Appendix C. In addition, each layout determined a set of basic requirements with reference to the selected level I CR. Later on the final list of design driver attributes/FRs (shown in Table 3-29) was then generated by selecting the common and most frequent attributes through the process of overlaying and comparing all layouts.

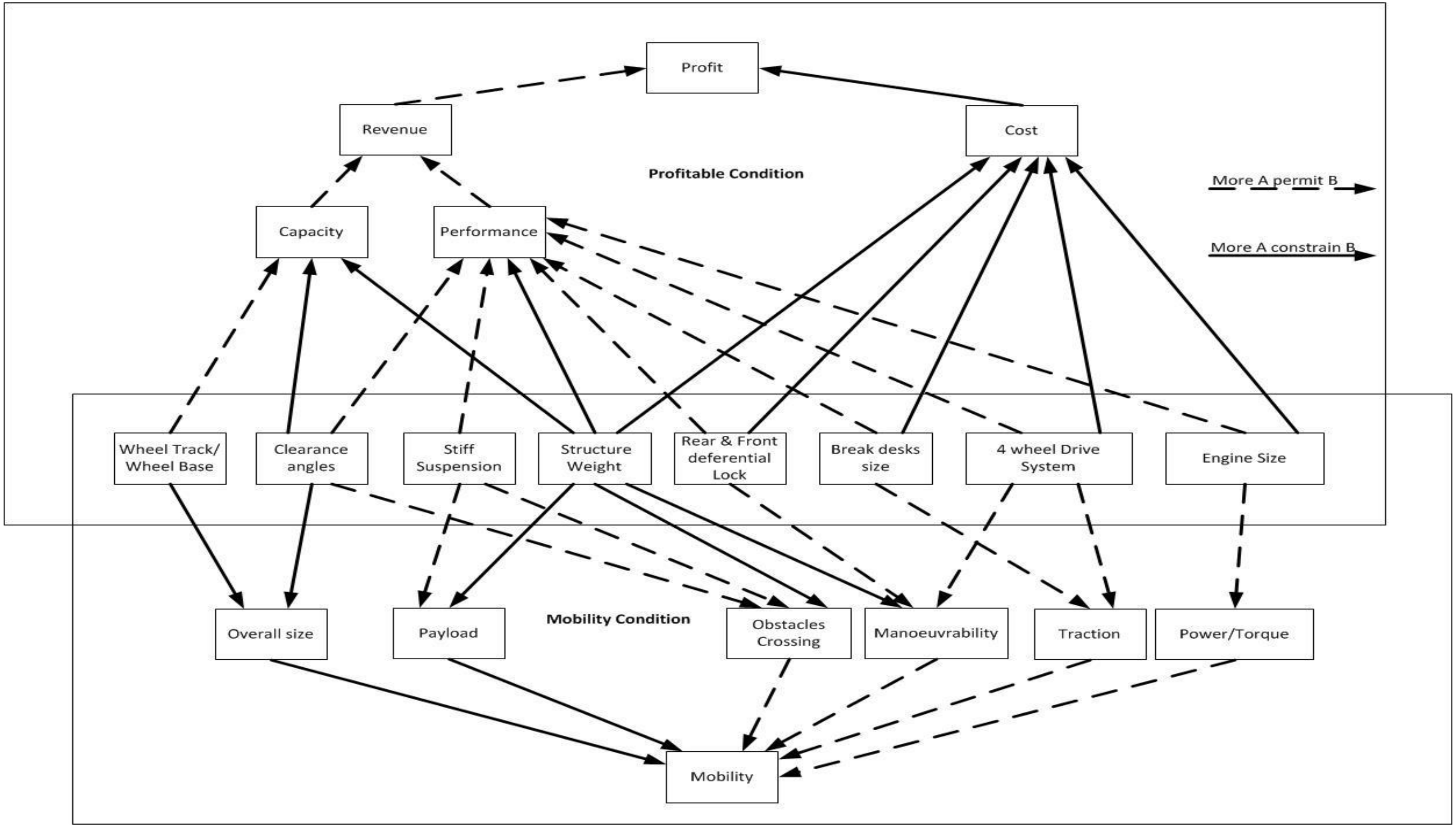


Figure 3-6 Level I Design Drivers -mobility

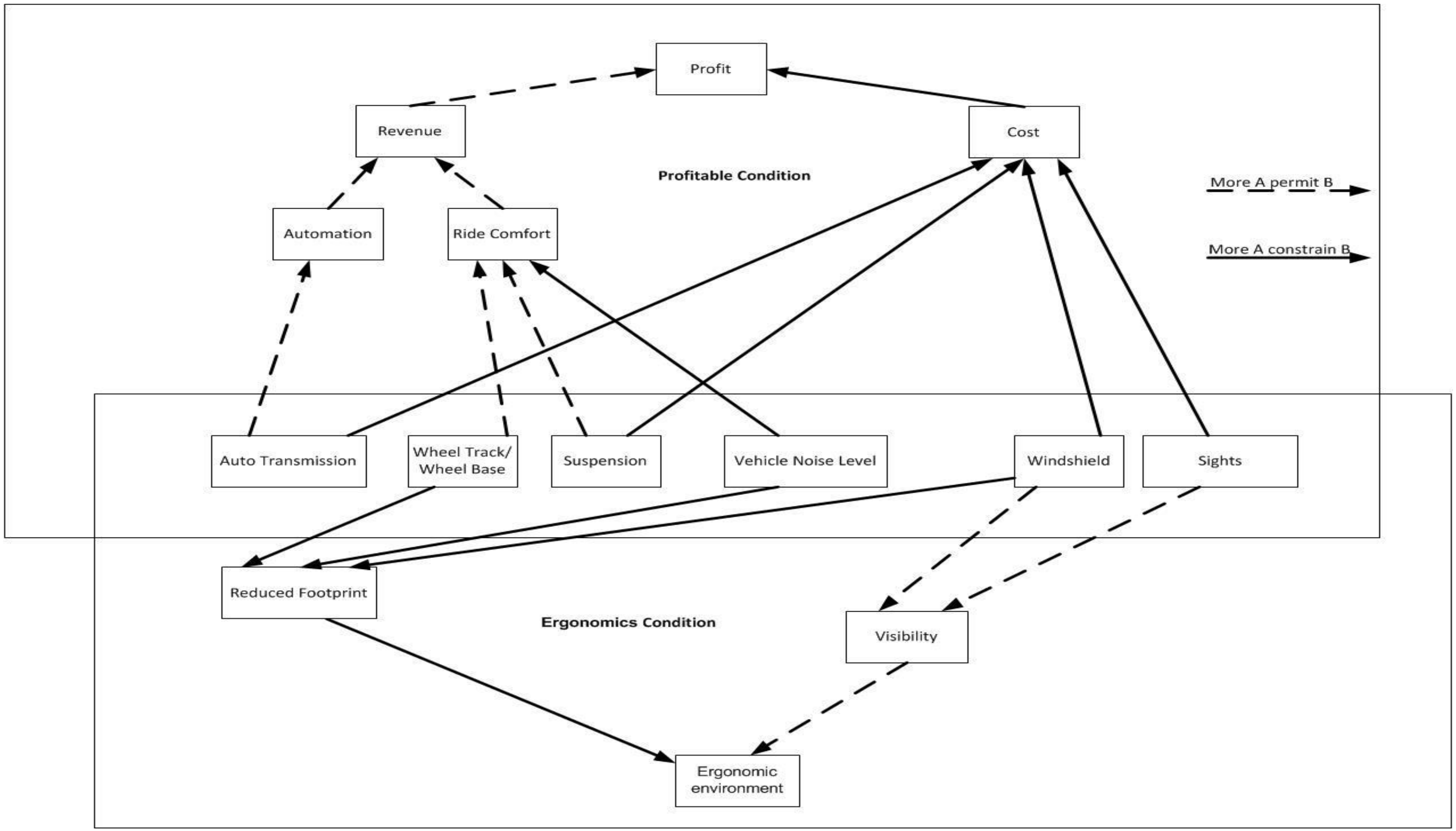


Figure 3-7 Level I Design Drivers – ergonomics

Table 3-29 Final level I FRs

No.	Functional Requirement	No.	Functional Requirement
1	Top speed	14	Differential Lock
2	Wheel Track/Wheel Base	15	Windshield
3	Clearance Angles (Approach, Departure, Ramp)	16	Vehicle Noise Level
4	Ground Clearance	17	suspension system
5	Climbing ability	18	High strength lifting hocks
6	Side Slop	19	High strength detachable/foldable crew and
7	Ditch crossing, Fording	20	Sights
8	Protection level	21	Communication System & GPS Antenna
9	Cruising Range	22	Transmission
10	Armament calibre	23	Max Payload
11	High capacity electrical alternator, High capacity	24	Curb Weight
12	Turning Radius	25	Engine power
13	4 wheel Drive System		

Finally, the functional requirements generated by the design drivers (listed in the above table) were tabulated to complete the QFD process. While doing so, the direction of improvement for each requirement was also included. This facilitates determination whether to aim to maximise, minimise, or just aim to achieve the set targets for a given functional requirement. This outcome is as shown in Table 3-30, which represents the common FRs and their direction of improvement.

Table 3-30 Common functional requirements

Column #	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**
Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)	▲	▲	▲	▲	x	x	x	x	▲	x	▲	▼	x	x	x	▼	x	x	x	x	x	x	▲	▼	▲
Quality Characteristics (a.k.a. "Functional Requirements" or "How s") / **Demanded Quality** (a.k.a. "Customer Requirements" or "Whats")	Top speed	Wheel Track/Wheel Base	Clearance Angles (Approach, Departure, Ramp)	Ground Clearance	Climbing ability	Side Slop	Ditch crossing, Fording	Protection level	Cruising Range	Armament calibre	High capacity electrical alternator, High capacity battery,	Turning Radius	4 wheel Drive System	Differential Lock	Windshield	Vehicle Noise Level	suspension system	High strength lifting hocks	High strength detachable/foldable crew and bed roll bars	Sights	Communication System & GPS Antenna	Transmission	Max Payload	Curb Weight	Engine power

Legend	
▼	Objective Is To Minimize
▲	Objective Is To Maximize
x	Objective Is To Hit Target

Stage 4. Relationship Matrix

The ‘relationship matrix’ rates the importance of the relationship between customer needs and the provided ability to meet those needs. Essentially the question being posed is, "what is the strength of the relationship between the functional requirements and the customer requirements?" Broadly speaking, relationships can either be weak, moderate, or strong. As outlined previously, these states have been assigned numeric values of 1, 3 or 9 respectively here.

Table 3-31 and Table 3-32 show a real case relationship matrix analysis for both QFD modes.

Stage 5. Correlation Matrix Stage

The term ‘House of Quality’ evolved because the correlation matrix resembles a ‘house with a roof’. This matrix examines how each functional requirement impacts other requirements as shown in Table 3-33. If a requirement has a positive effect on another requirement it is expressed as + while a negative impact is represented by ‘-‘. For example increasing armour protection will negatively affect the weight and mobility (-), while having better optical system will enhance range and accuracy (+). Thus strong negative relationships between functional requirements are important indicators, and work should be done to eliminate such physical contradictions.

Table 3-31 AHP based QFD, relationship matrix

Quality Characteristics (a.k.a. "Functional Requirements" or "How s") / Demanded Quality (a.k.a. "Customer Requirements" or "Whats")	Top speed	Wheel Track/Wheel Base	Clearance Angles (Approach, Departure, Ramp)	Ground Clearance	Climbing ability	Side Slop	Ditch crossing, Fording	Protection level	Cruising Range	Armament calibre	High capacity electrical alternator, High capacity battery	Turning Radius	4 wheel Drive System	Differential Lock	Windshield	Vehicle Noise Level	suspension system	High strength lifting hocks	High strength detachable/foldable crew and bed roll bars	Sights	Communication System & GPS Antenna	Transmission	Max Payload	Curb Weight	Engine power
Max speed	⊖	▲						○					○		○	▲	○					⊖	⊖	⊖	⊖
Slop climbing		▲	○	○	⊖	⊖							⊖	○			○					⊖	○	⊖	⊖
Obstacles crossing		⊖	⊖	⊖	○	○	⊖					⊖	⊖	⊖			⊖					○	○	○	⊖
Natural Terrains Interaction	⊖	⊖	⊖	⊖									⊖	⊖			⊖					⊖	⊖	⊖	⊖
Manoeuvrability	⊖	⊖	⊖	⊖				○				⊖	⊖	⊖			⊖					⊖	⊖	⊖	⊖
Medium-Heavy w eight w eapons	○	○			○	○		○	⊖	⊖	⊖		○		⊖		⊖		⊖	⊖	○	○	⊖	⊖	⊖
Visibility		▲		○				○							⊖					⊖					
Ride Comfort		○		○									○				⊖					○		○	○
Protection from outside environment				○				⊖							⊖				⊖						
Reduced Footprint		▲													▲	⊖									
Ballistic Protection								⊖		○					○										
Rollover Protection		○																	⊖						
Light-Medium w eight w eapons										⊖													⊖	○	
Precision munitions										○	○									⊖	⊖		⊖	○	
Parachute deployment		⊖															⊖	⊖						⊖	
Transportability by C-130		⊖															○	⊖						⊖	
Transportability by trailer		⊖															○	⊖						⊖	
Compatibility w ith Airlift by helicopters		⊖															⊖	⊖						⊖	
Overall size limits		⊖	⊖	⊖																					
VHF/ UHF Radios											⊖								○				⊖	⊖	
GPS											○								▲		⊖		⊖	▲	
Number of crew members		⊖																		▲	⊖			⊖	○
Payload								⊖					○				⊖					⊖	⊖	⊖	⊖
Diesel Engine	⊖	○							⊖							⊖						○	○	⊖	⊖
2 w ay, audio and video data											⊖									⊖	⊖		▲	▲	

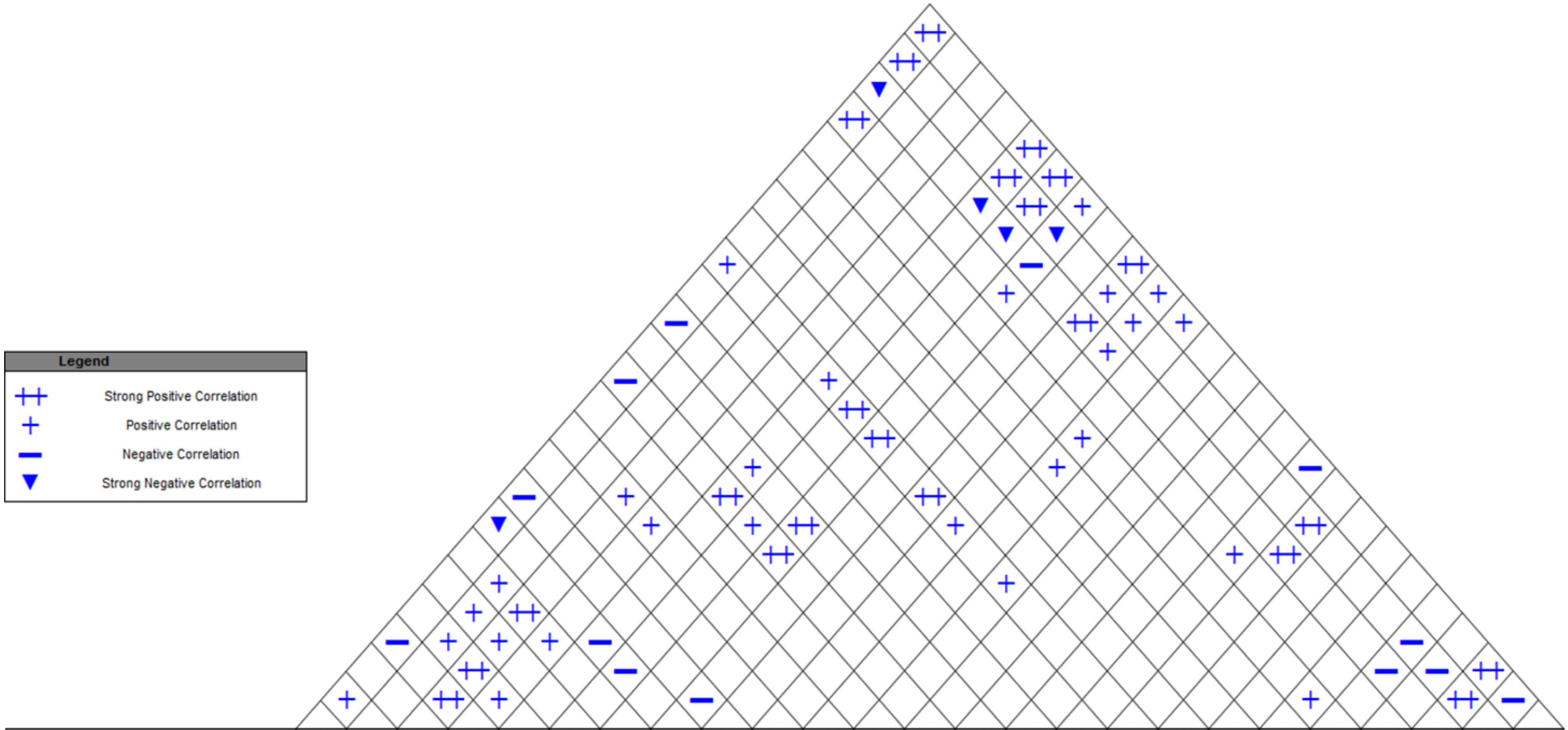
Legend		
⊖	Strong Relationship	9
○	Moderate Relationship	3
▲	Weak Relationship	1

Table 3-32 Kano based QFD, relationship matrix

Demanded Quality (a.k.a. "Customer Requirements" or "Whats") / Quality Characteristics (a.k.a. "Functional Requirements" or "Hows")	Top speed	Wheel Track/Wheel Base	Clearance Angles (Approach, Departure, Ramp)	Ground Clearance	Climbing ability	Side Slop	Ditch crossing, Fording	Protection level	Cruising Range	Armament calibre	High capacity electrical alternator, High capacity battery,	Turning Radius	4 wheel Drive System	Differential Lock	Windshield	Vehicle Noise Level	suspension system	High strength lifting hocks	High strength detachable/foldable crew and bed roll bars	Sights	Communication System & GPS Antenna	Transmission	Max Payload	Curb Weight	Engine power
Run-Flat Tires	Θ	▲		O	O	O		Θ	O								Θ					O	Θ	Θ	
Capability to be air deployed		Θ	O	Θ													Θ	Θ	Θ		O		Θ	Θ	
Auxiliary fuel tank		Θ							Θ														Θ	Θ	
Adjustable seats		Θ																							
Tire inflation system				Θ	O	O	O		▲		O						O					O	O		
GPS & Satellite Navigation system											Θ										Θ				
7.62-12.7 swivel gun mounts								Θ		Θ									O					O	
Modular structure design		Θ	O	O				O					O		Θ		O	O	Θ			O	Θ	Θ	
7.62 Remote weapon station		O			O	O		O		Θ	Θ						Θ		Θ	Θ	Θ		Θ	Θ	O
Unmanned variant	O	O	O					O		O	Θ	O		O		O	O		O	Θ	Θ	O	Θ	Θ	Θ

Legend		
Θ	Strong Relationship	9
O	Moderate Relationship	3
▲	Weak Relationship	1

Table 3-33 Correlation matrix



Column #	Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)	Quality Characteristics (a.k.a. "Functional Requirements" or "Hows")
1	▲	Top speed
2	▲	Wheel Track/Wheel Base
3	▲	Clearance Angles (Approach, Departure, Ramp)
4	▲	Ground Clearance
5	x	Climbing ability
6	x	Side Slop
7	x	Ditch crossing, Fording
8	x	Protection level
9	▲	Cruising Range
10	x	Armament calibre
11	▲	High capacity electrical alternator, High capacity battery,
12	▼	Turning Radius
13	x	4 wheel Drive System
14	x	Differential Lock
15	x	Windshield
16	▼	Vehicle Noise Level
17	x	suspension system
18	x	High strength lifting hocks
19	x	High strength detachable/foldable crew and bed roll bars
20	x	Sights
21	x	Communication System & GPS Antenna
22	x	Transmission
23	▲	Max Payload
24	▼	Curb Weight
25	▲	Engine power

Stage 6. Organisational Difficulty Stage

This stage takes into account the organisational difficulty of the design attributes. Based on the resources and capabilities of the organisation, a mark representing the level of difficulty, ranging from 0-10, is assigned to each functional requirement as shown in Table 3-34 and Table 3-35 for both the AHP and Kano modes respectively.

Stage 7. Target Values for Functional Requirements

At this stage, target values are established for each functional requirement. Target values represent "how much" for the functional requirement. This figure then acts as a base-line for subsequent comparison. This approach is highlighted in Table 3-34 and in Table 3-35. Since a dual mode QFD approach is used, the highest target value between the AHP and Kano based QFDs was selected and taken forward for further design and development of the MATV.

Stage 8. Absolute Importance

The absolute importance is numerically calculated for each functional requirement. It is defined as the product of the cell value and the customer importance rating (Creative Industries Research Institute, 2007) as shown in Table 3-34 and Table 3-35 for the AHP and Kano approaches respectively.

Table 3-34 AHP based QFD, target values

Target or Limit Value	75 Km/h	2350mm/1600mm	75 deg, 65 deg, 18 deg	350mm	60%	40%	500mm, 500mm	soft skin-B6 (based of variant type)	500Km	7.62mm-12.7 (based of variant type)	300+ watt, 12V approx. 15 Ah	5 m	yes	yes	yes	75 dB	Independent double wishbone	yes	yes based of variant type)	yes based of variant type)	yes based of variant type)	CVT	500 kg	700 Kg	60 hp
Difficulty (0=Easy to Accomplish, 10=Extremely Difficult)	7	7	4	7	2	1	4	8	7	6	5	8	2	2	1	9	6	4	7	5	5	6	8	9	8
Max Relationship Value in Column	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
Weight / Importance	152.1	343.4	138.0	179.2	64.0	64.0	35.9	161.7	77.5	114.3	116.3	67.2	182.8	109.3	145.9	88.8	301.2	115.9	134.5	151.8	143.6	221.5	364.5	491.1	307.4
Relative Weight	3.6	8.0	3.2	4.2	1.5	1.5	0.8	3.8	1.8	2.7	2.7	1.6	4.3	2.6	3.4	2.1	7.1	2.7	3.1	3.6	3.4	5.2	8.5	11.5	7.2

Table 3-35 Kano based QFD, target values

Target or Limit Value	60 Km/h	2350mm/1600mm	75 deg, 65 deg, 18 deg	350mm	60%	40%	300mm, 300mm	soft skin-B6 (based of variant type)	500Km	7.62mm-12.7 (based of variant type)	500+ watt, 12V approx. 20 Ah	5 m	yes	yes	yes	75 dB	Independent double wishbone	yes	yes based of variant type)	yes based of variant type)	yes based of variant type)	CVT	500 kg	700 Kg	60 hp
Difficulty (0=Easy to Accomplish, 10=Extremely Difficult)	7	7	4	7	2	1	4	8	7	6	5	8	2	2	1	9	6	4	7	5	5	6	8	9	8
Max Relationship Value in Column	9	9	3	9	3	3	3	9	9	9	9	3	3	3	9	3	9	9	9	9	9	3	9	9	9
Weight / Importance	127.7	443.9	84.4	259.6	90.3	90.3	30.9	267.2	143.2	182.6	259.1	22.1	27.6	22.1	82.7	22.1	363.0	131.7	310.9	139.1	262.9	115.8	560.1	558.4	90.6
Relative Weight	2.7	9.5	1.8	5.5	1.9	1.9	0.7	5.7	3.1	3.9	5.5	0.5	0.6	0.5	1.8	0.5	7.7	2.8	6.6	3.0	5.6	2.5	11.9	11.9	1.9

3.4 Concept Development

In this phase, a set of activates are defined to establish the best concept that will simultaneously fulfil both customer needs and engineering requirements.

As described earlier in the introduction chapter, the concept development phase consists of three main activities:

- Functional modelling
- Product architectural development
- Concept engineering

Due to time limitation, this research study has dealt with the first two activities at system level, and with sample implementation. While concept engineering has not been investigated, sufficient ground work has been undertaken to establish a concept as part of future work

The functional modelling performed in this phase is complemented by the QFD analysis. In this regard, the QFD process concentrates on incorporating the customer wants into the final product, whereas the functional modelling stage concentrates on how to achieve the final product functionality based on the customer wants.

3.4.1 Functional Modelling

Functional modelling is an important tool for relating customer needs to functional descriptions (Otto and Wood, 2001). A set of technologies are then created and selected based on the generated descriptions.

During this stage a systematic approach has been used to generate a comprehensive functional diagram for the MATV vehicle, covering all the customer needs which are refined by the QFD process.

As part of this process a diagram known as a Hierarchical Function Structure (Otto and Wood, 2001) is generated. This structure is evolved by developing the functions hierarchy that starts from main product function down to primary sub-functions. By expanding functions to sub-functions, this diagram finally links functions to technologies that will fulfil a function.

The functional hierarchy diagram is constructed based on the following six categories:

- Main MATV vehicle function
- MATV base model function
- User requirements (Main functions)
- Supporting sub-functions
- Micro functions (Basic functions)
- MATV vehicle variants (Enhanced functionalities)

Each category is described and justified separately, before all categories are combined into one complete system of systems diagram (see Appendix D for a complete hierarchical function structure). The micro functions diagrams are discussed later in the results section.

3.4.1.1 Hierarchical Function Structure- Main vehicle function

This category contains one main function block, as shown in Figure 3-8. However, this will be the basis for the derivation of all subsequent functions.

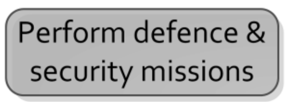


Figure 3-8 Main MATV vehicle function

This function represents the main mission of the 1st generation KADDB MATV; it was intended to be the same for the 2nd generation, as one of the objectives of this research is to appreciate the design and product development methodology using the MATV as a case study. Essentially, via this process, the author is striving to improve the design of the 2nd generation MATV through refinement and optimisation of the current design (1st generation) to obtain a competitive 2nd generation MATV.

Based on this remit, the MATV is intended to perform two major roles inherited from the main roles of the 1st generation MATV, namely supporting: (1) missions requiring rapid deployment and manoeuvrability, and; (2) internal security – where a more approachable appearance is desirable.

Furthermore, in order to generate a function diagram that covers the two major roles with a spectrum of variants for each role, modular design functionality was achieved by generating a base model functional diagram, coupled with supplementary functional diagrams covering all selected variants derived from the QFD results.

3.4.1.2 Hierarchical Function Structure - MATV Base Model Function

The main purpose of the base model function was to establish a common base functionality for all future variants (platforms). By doing this, there will be an overall cost saving due to the subsequent sharing of components and manufacturing processes between all variants. A modular approach may increase the development cost a little due to the use of the modularity concept in the MATV development process (Muffatto, 1999), but it will also reduce the subsequent logistic burden.

A more detailed discussion regarding the modularity concept will be covered in a later section on the modularity function.

It is our intension that the base model functionality can serve as one type of the intended variants, known as the Rapid Effect Vehicle, as shown in Figure 3-9. This variant will be represented by the base model functionality – i.e. functions all variants must poses to perform and function effectively in the battlefield.

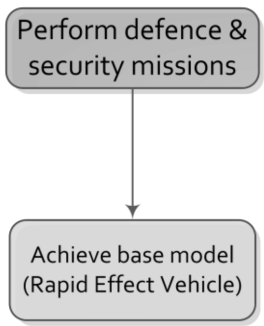


Figure 3-9 MATV base model function

By doing so, two major contributions are achieved (a base model ready for upgrade, and a rapid effect vehicle), which will add more flexibility to the base model MATV, due to the immediate implementation as rapid effect vehicle, rather than just waiting for the upgrading process only.

3.4.1.3 Hierarchical Function Structure - User Requirements Functions (Main Functions)

In this stage, all sub-functions contributing to the base model function were identified. This approach helps to ensure full compatibility with the user requirements, as well as better synchronisation with the QFD results of level I specifications (Table 3 -1).

Based on the above, the following six sub-functions were identified:

1. Achieve Mobility
2. Achieve lethality
3. Achieve Survivability
4. Support battlefield management system
5. Achieve Modularisation
6. Account for general product development considerations

The Hierarchical Function Structure is presented in Figure 3-10.

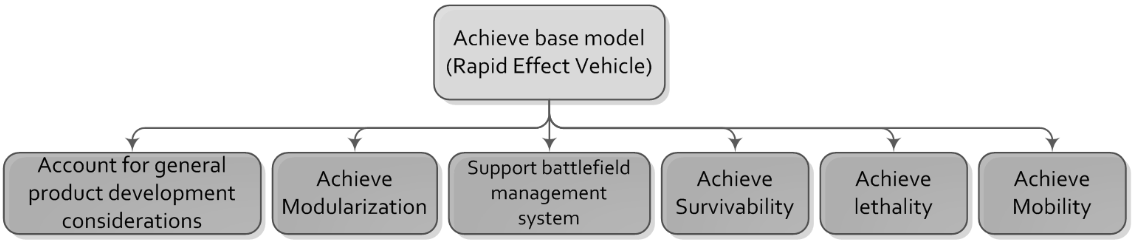


Figure 3-10 User requirements functions

By asking the how-question, each sub-function is further analysed and decomposed in to lower level sub-functions until no further decomposition is possible. This level is termed as the micro function (Basic functions) level, at which the basic product development technologies can be derived and utilised for the MATV vehicle development process.

3.4.1.3.1 Achieve Mobility Function

Mobility is one of the main functions that need to be achieved in order to develop a well-balanced all-Terrain vehicle. This function resulted in the highest weighted priority during the customer need analysis phase

The mobility function is further subdivided into three sub-functions, namely: Strategic, Operational and Tactical, as shown in Figure 3-11.

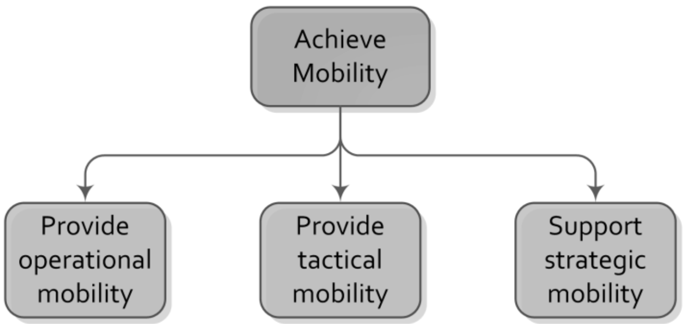


Figure 3-11 Mobility function

At the top level, strategic mobility allows the commander to relocate forces and assets under his or her control to meet the required fighting strategy. Therefore strategic mobility is defined as the ability of the vehicle to be deployed in the battlefield theatre. In this regard forces and assets will be moved from the storage depot, peace time regimental locations and safe houses. Thus strategic mobility delivers the assets up to sea or airport. Next the commander would wish to deploy the force from the port to operational theatre for which these valuable assets must be transported as quickly and safely as possible. Thus an operational mobility is the ability of the vehicle to be transported to the operation zone. This function is important to reduce wear and tear on the vehicle and its crew. This function also ensures that the vehicle upon reaching its destination will be available to participate in the action. Finally tactical mobility is the ability of the vehicle to travel over multi terrains (Khalil et al., 1999) with speed while ensuring crew comfort. This function also covers the gradability and obstacle crossing.

Each of the above levels was logically broken down using three stages of supporting sub-functions and one stage of micro functions (Basic functions).

Regarding the strategic mobility, the main concern was to achieve rapid deployment through the fastest practical means such as by air or sea; sea may not represent a shortened time, but will often allow the fastest overall force deployment to organise forces to meet the desired fighting strategy.

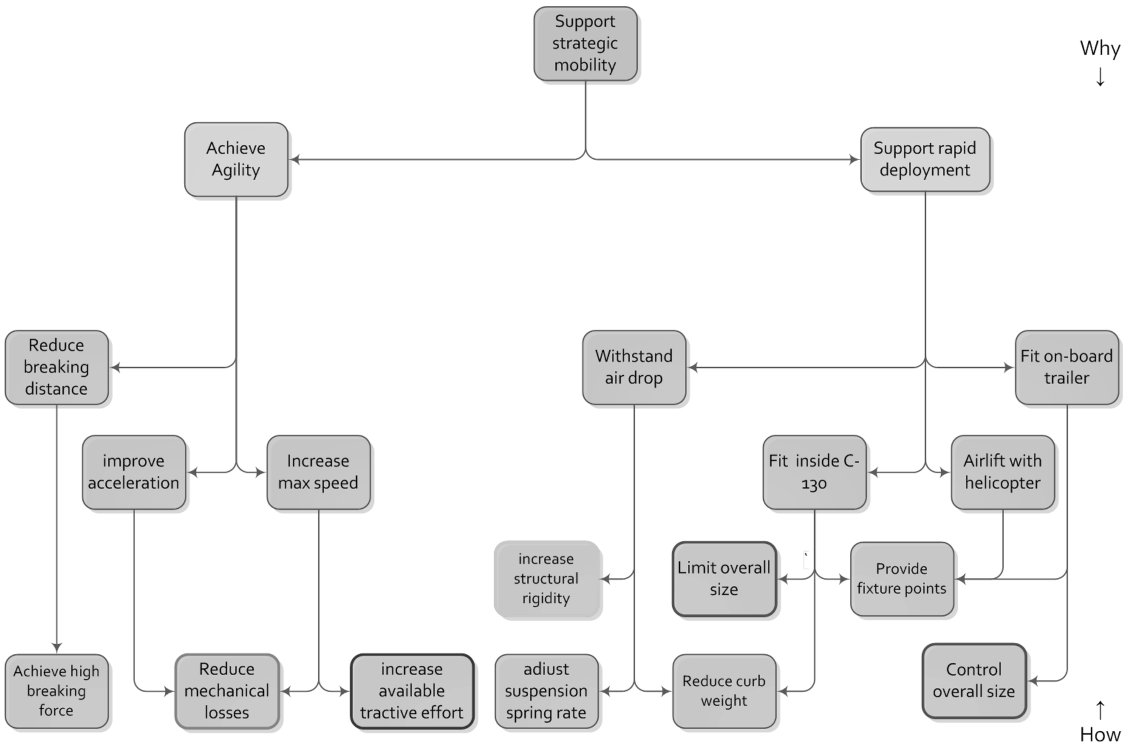


Figure 3-12 Strategic mobility function

The tactical mobility is a more demanding function as it provides the vehicle with the ability to operate in military environments. To that end, the main focus was to achieve agility; manoeuvrability, obstacle crossing, and all-terrain drive capabilities as shown in Figure 3-13 .

The agility function will provide a quick and responsive vehicle movement within the battlefield or mission.

In parallel, the manoeuvrability function is intended to provide the vehicle with the ability to drive through confined areas, rapidly changing terrain (sand, soil and wet mud, etc.) and to allow it to be able to quickly avoid and cruise through the terrain-based obstacles during the mission. Therefore, two second level sub-functions where involved, including reduced turning radius and improved dynamic stability.

The third level includes optimised weight distribution, steering, and suspension geometries as a pre-requisite to achieve the above two level functionalities.

The obstacle crossing functionality included fording, ditch crossing, step and slope climbing sub-functions, and in order for those to be achieved, a number of third level sub functions were introduced including, improved water insulation, increased ground clearance, increased available tractive effort, reduced mechanical losses, increased traction and breaking, and increased clearance angles.

Finally, the drive all-terrain functionality was intended to give the vehicle the ability to move across different terrain configurations, including sand, rocks, mud and vegetation fields. Slope climbing was also included in this function. From the functional diagram it is also clear that some functions are interlinked and support each other.

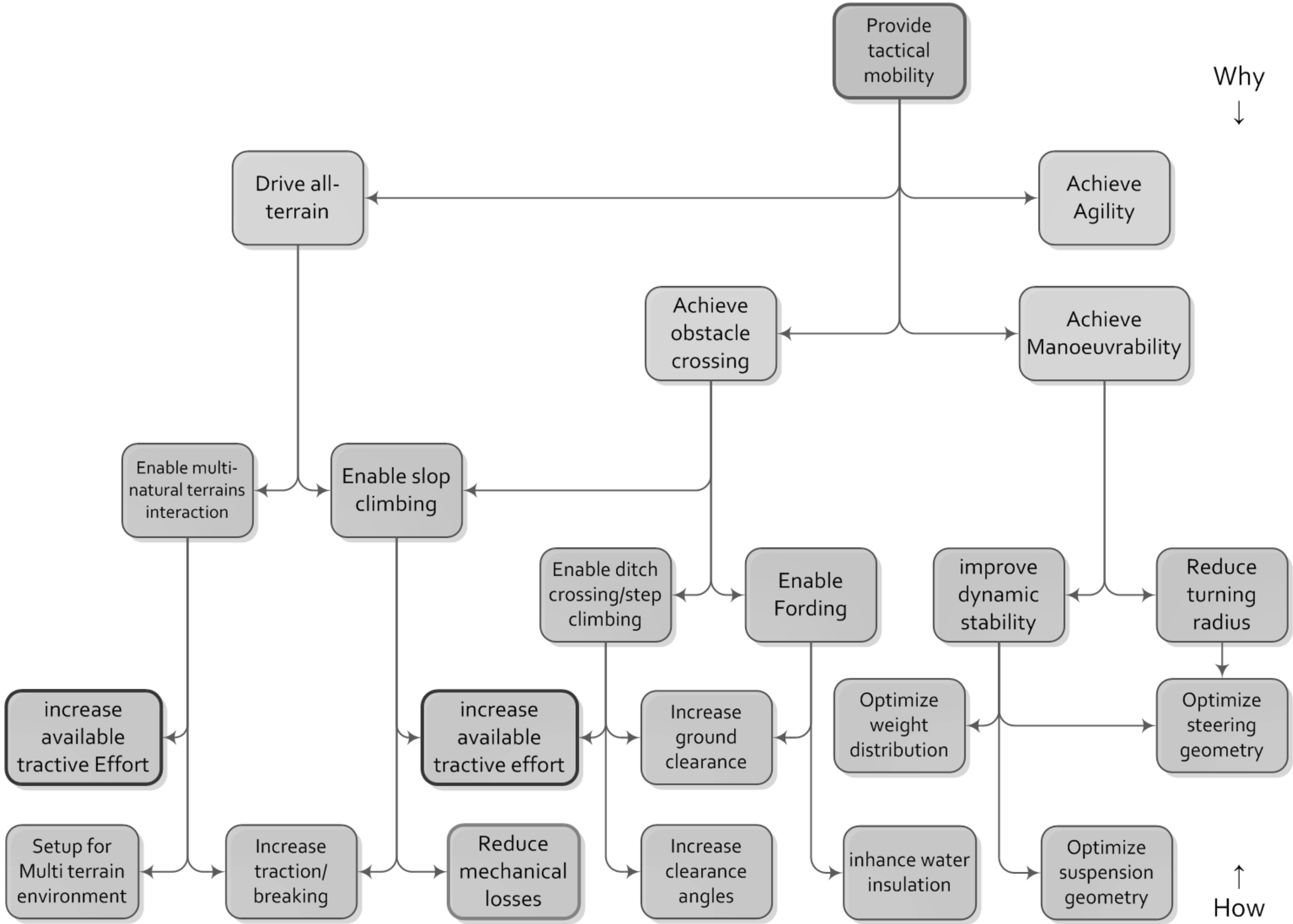


Figure 3-13 Tactical mobility function

For the operational mobility concerning the crew, the main concern was to provide transportation to operators, passengers and cargo to and within the battlefield. This cargo could range from special equipment and logistics supplies to ammunition and weapon systems.

For the above, passenger and cargo transportation and drive all-terrain were included as the first level sub-functions. Moreover, in the second level, the availability of passenger seats was included as supporting this higher level function, along with the need to increase the size of the cargo payload and the ability to withstand the forces/mechanical stresses generated by the resultant added weights of a carried load.

In order to support the added weight and size of the vehicle, more detailed level three functions are included that indicates the preparation needed to support the second level functions, including the need to have a suitable wheelbase and wheel track lengths. This level also requires for spring rate adjustment according to the gross vehicle weight, and highlights the need to have an improved vehicle tractive effort and structure rigidity as shown in Figure 3-14.

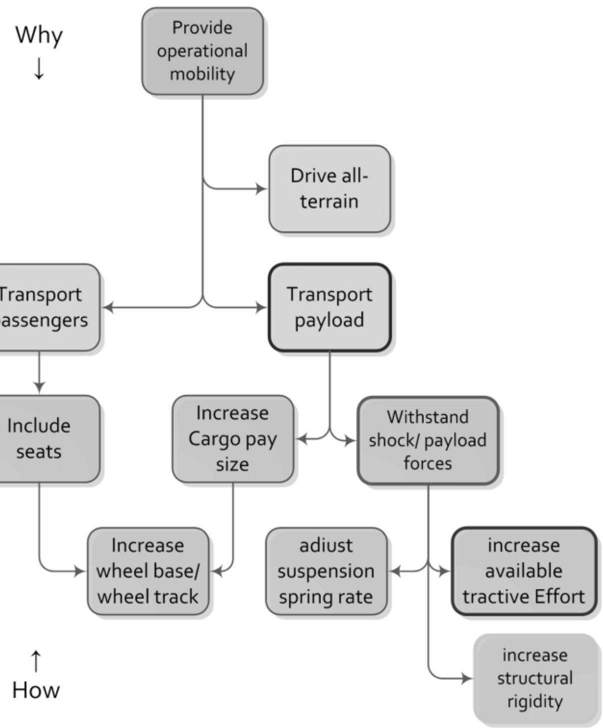


Figure 3-14 Operational mobility function

3.4.1.3.2 Achieve lethality Function

The lethality requirement attained a high priority rating during the customer need analysis phase. In this regard, it was necessary to address this importance within the development process of the second generation MATV.

In order to do so, the lethality function was composed of two sub-functions including the capability of providing direct and indirect lethal effect and precision attack as shown in Figure 3-15.

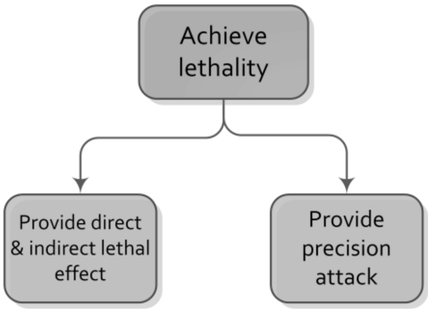


Figure 3-15 Lethality function

The direct and indirect lethal effect functions indicate the fire power effects that can be delivered by the vehicle when fitted with suitable weapons. Being a light weight MATV, the size and the amount of weapons are constrained by the size and payload of the vehicle.

The vehicle design intends to support light-medium weight direct and indirect fire weapons, including integration of an up-to 7.62mm remote weapon station system by providing the ability to fire under armour, a function that provides enhanced protection. To fulfil this function and to allow weapon to aim and track the target an additional electrical power supply is demanded by the above mentioned weapon system.

Decomposing further, the second level sub-functions address the needs of the vehicle to include a swivel gun mount capable of supporting an up-to 12.7mm machine gun and a power outlet(s) for electric operation if required in the future. The implication of extra future power means that electric architecture would need high power density batteries and an alternator to meet the future need of electric power operated weapon and other ancillary equipment.

In order to achieve the above functions, it is also necessary that the vehicle design should allow for future hardware/power upgrades. Therefore the base model vehicle should be fitted with higher amp cables as a standard feature, in order to reduce the time and cost of potential future upgrading work demanding higher power. The resultant lethality functional diagram is shown in Figure 3-16.

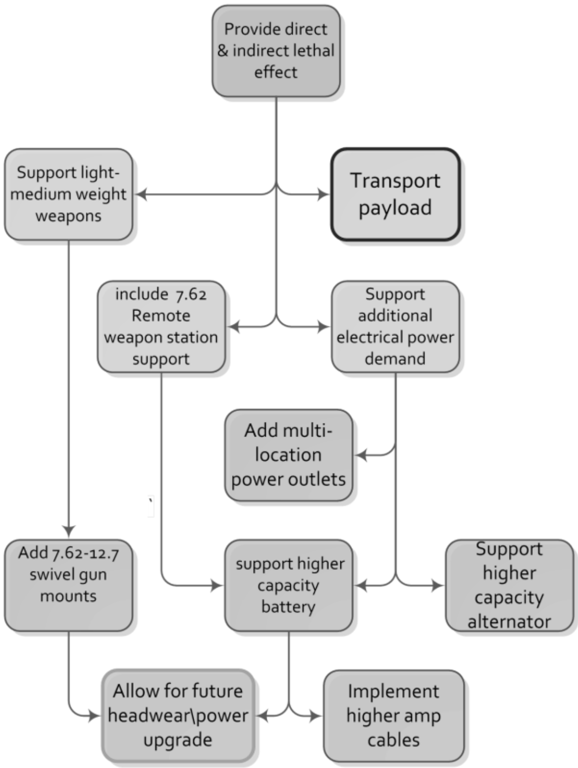


Figure 3-16 Provide direct & indirect lethal effect function

The function that provides precision attack is mostly shared by the sub-functions that provide direct and indirect lethal effect functions. However, a specialised sub function was added to ensure vehicle will support precision munitions.

The precision munitions sub-function includes advanced systems such as radars, infrared, IR imaging, and electro-optical guided weapons. In that matter, the function of providing precision attack requires even more careful planning for any future power upgrade

The full break down of sub-functions supporting the ‘Provide Precision Attack’ function is shown in the Figure 3-17.

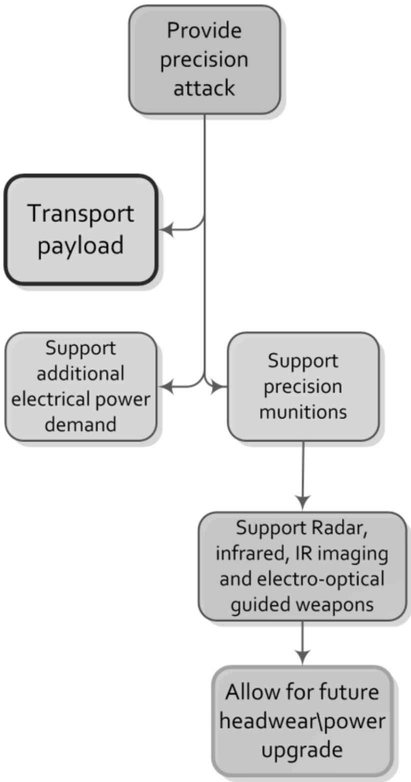


Figure 3-17 Provide precision attack function

3.4.1.3.3 Achieve Survivability Function

With a high weighted priority score of 14.0% as shown in Table 3-14, vehicle survivability is a customer requirement. In that, it is necessary to ensure that the final product will provide a suitable level of survivability without compromising other functions such as the mobility or lethality functions.

Based on the above, the survivability function was investigated from different aspects, including the vehicle’s vulnerability, and susceptibility which are two of the main factors that support the achievement of this (survivability) function (Ball, 2003), as shown in Figure 3-18.

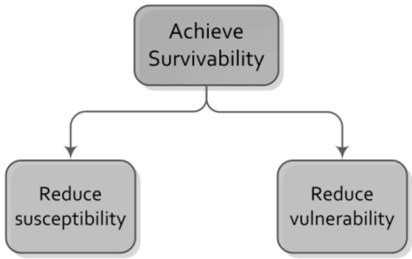


Figure 3-18 Survivability function

Vulnerability in the military context is defined as the failure to resist a hit or effects of an intimidating situation (Ball, 2003). Consequently, it is important to achieve a certain level of vehicle protection in order to reduce vulnerability. This implies adding ballistic and tyre protection to the vehicle as shown in Figure 3-19.

However, being a light MATV, the vehicle protection in this case was sensitive to maintaining the low vehicle weight. Therefore, a soft-skinned (No armour) solution was proposed for the base model, with a functional option to support future add-on armour panels for a protected mobility variant of the MATV, which could be designated for missions with standard mobility requiring high protection in a hostile environment.

Nevertheless, the base mode was included with run-flat tires functionality as a standard feature, as it had minimal effect on the overall weigh of the base model, yet it provided a high level of protection to the tires.

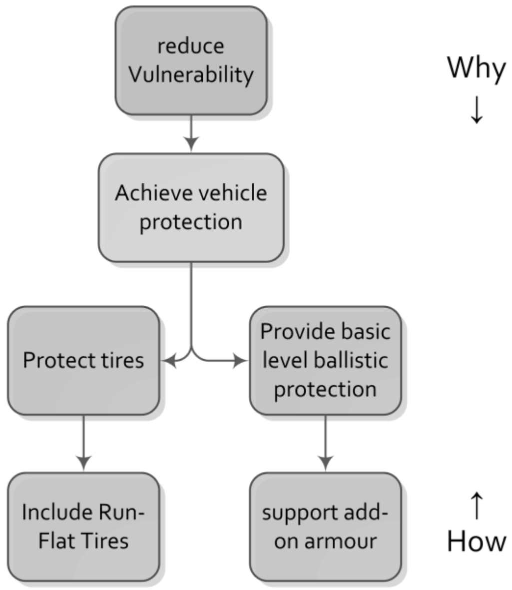


Figure 3-19 Vulnerability function

The Susceptibility function is defined as the degree of inability to escape a threat or a hit (Ball, 2003). This function is particularly important to the MATV base model and all future variants, as it will help in improving the vehicle survivability without compromising the overall weight.

Here the main goal was to reduce susceptibility by a supporting situational awareness system, as well as by managing the vehicle signature as shown in Figure 3-20.

For the situation awareness sub-function, there are many systems out in the market that can be added to the base model or any future variant of the MATV. These include wide variety of electro-optical/infrared sensors; however, here the main concern was to provide the vehicle with a functionality that supports day/night vision camera(s).

The function of managing the vehicle signature on the other hand included two sub-functions: the first was the reduction of visual spot of the vehicle, which was achieved by implementing camouflage paint; with the second reduction of the vehicle noise level, which was achieved by using sound insulation materials.

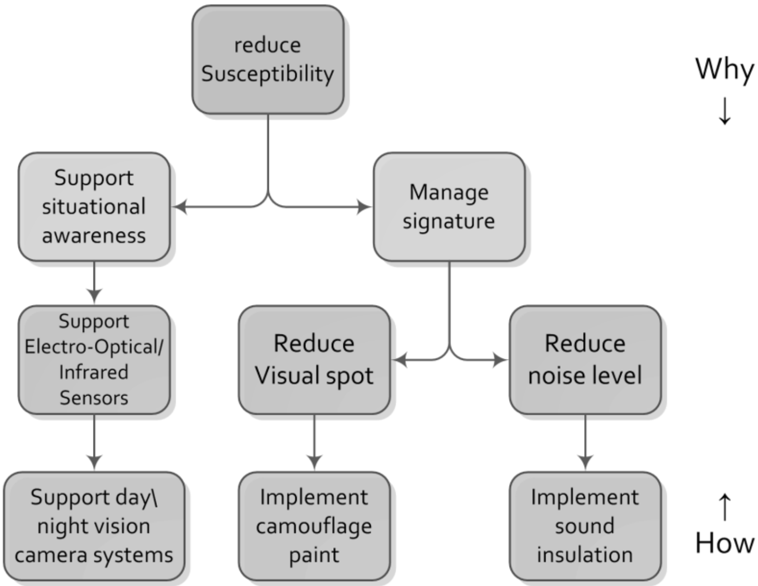


Figure 3-20 Susceptibility function

3.4.1.3.4 Achieve Modularisation Function

The MATV is a complex system due to its large number of sub-systems and components that need to be integrated together in order to allow the vehicle to function successfully. In addition, the MATV vehicle is expected to operate in various types of defence and security missions. This results in further complex system design that would be impossible to design for and manufacture in their entirety.

To overcome this problem, a modularity concept was introduced that would offer huge potentials in terms of simplifying and managing the complex systems of the vehicle by breaking them down into modules (Pandremenos et al., 2009).

By achieving the modularisation function, it was possible to implement the base model concept as a platform. By combining this with the quick customisation functionality, this approach allowed generation of a relatively large number of variants that are capable of performing a wide spectrum of defence and security missions, while still maintaining low development and production costs

(Muffatto, 1999), as well as the ability to operate the MATV simply and effectively during missions.

In order to achieve modularisation, an open architecture (Muffatto, 1999) is used for the base model vehicle as a supporting function as shown in Figure 3-21.

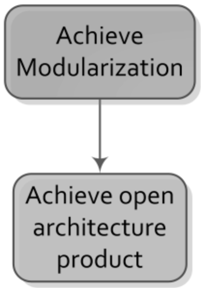


Figure 3-21 Modularisation function

The Open-Architecture Product (OAP) means that the developed system consists of modules that can be added or substituted to the main platform to obtain new products or enhanced features (Koren et al., 2013).

Based on the above, the OAP is achieved by producing a modular structure with open electric/electronic systems architecture. Furthermore, the sub-function of modular structure can be facilitated by insuring the following modular operators (Baldwin and Clark, 2000):

1. Components clustering; by grouping components with similar functionalities into modules.
2. Splitting systems into modules that interact across defined interfaces.
3. Components and systems augmenting/excluding; this means that a new structure can be obtained by adding or removing components.
4. Modules which can be substituting by switching between components which perform the same function.

In order to achieve the above it was necessary to allow the sub-systems/ components to interact with each other, and to unify systems/components interfaces to facilitate compatibility and integration.

For the sub-function of open electric/electronic systems architecture two second level sub-functions are introduced, the first of which is the sub-function of standardised form factor & connectors to ensure that any future system with the same standard specifications can be integrated with the MATV. The second sub-function is to standardise power levels which help to support power needs for different systems when developing new variants.

Finally, the standardisation process for the power levels, form factor and connectors must meet international and military standards. The overall function tree for the Open-Architecture Product is shown in Figure 3-22.

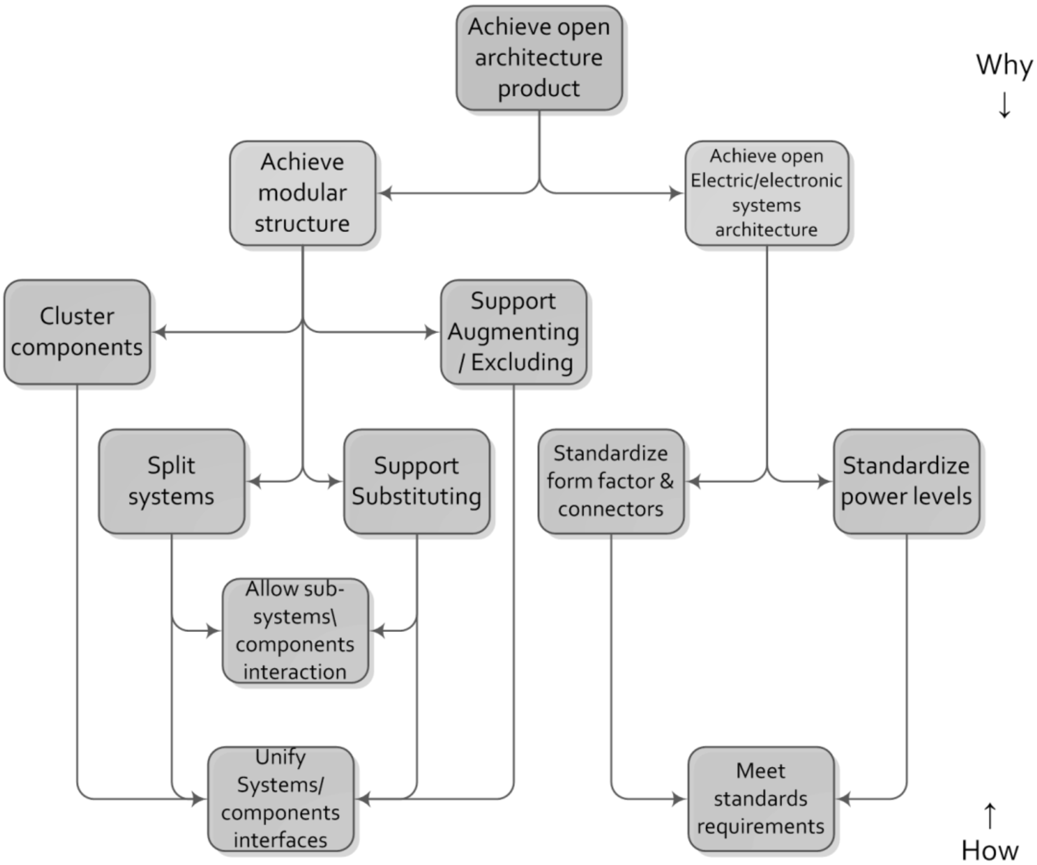


Figure 3-22 Open architecture product function

3.4.1.3.5 Support Battlefield Management System

The Battlefield Management System is considered an important function for fast and accurate decision making by offering and integrating the real-time situational picture and information on available resources.

Therefore, it was important that the MATV base model provide support to this system in terms of facilitating the addition and integration of the related equipment for any MATV variant. Furthermore, the battlefield management system includes threat detection, target tracking, and threat discrimination (Athans, 1987) as shown in Figure 3-23.

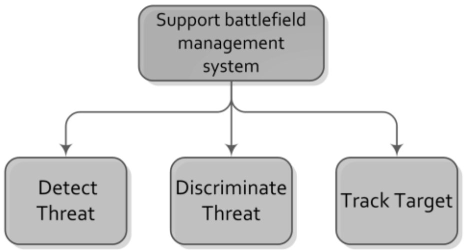


Figure 3-23 Support battlefield management system function

For the ‘detect threat’ function, the base model MATV needed to support different types of vision systems including a range of electro-optical and infrared sensors such as day and night vision camera systems, and thermal imagers as shown in Figure 3-24. Furthermore, the support function indicates that the base model design should allow for power supply and standard electrical interfaces including the space to accommodate supporting structure for future hardware installation.

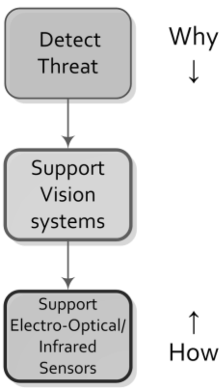


Figure 3-24 Detect threat function

The Track Target function is achieved through the supporting vision, navigation and communication systems as shown in Figure 3-25.

The 'communication system' support function includes supporting the installation of military radio systems such as HFV/HF and multiband radios. This will also support network-centric warfare through networking with peer vehicles and the command post.

The navigation support is a very important function as it gives an operator/vehicle an ability to accurately locate threats and friends during the battlefield. For that to happen, the navigation function is achieved by installing a GPS system, including MIL spec displays, GPS antenna, and receiver.

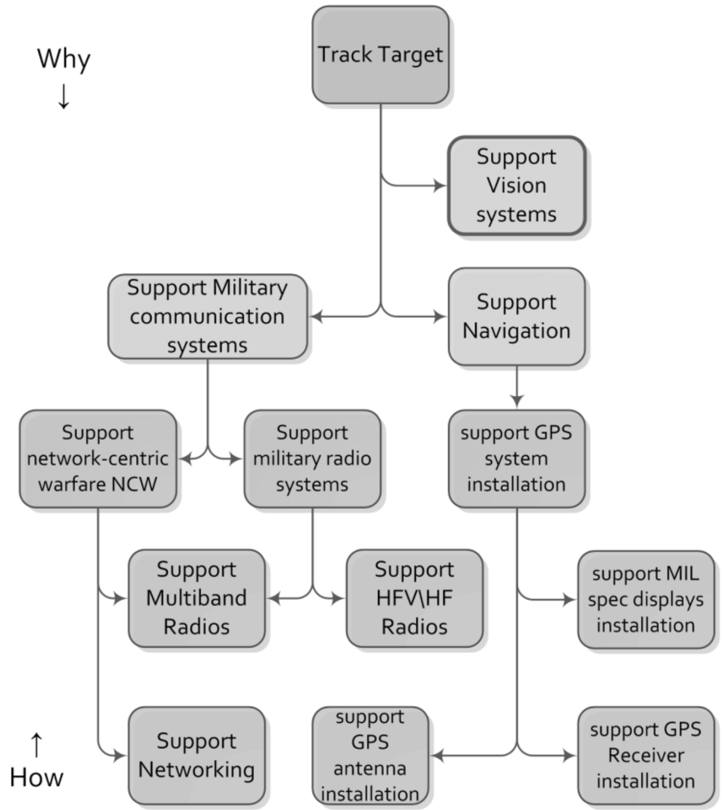


Figure 3-25 Track target function

The threat discrimination function (shown in Figure 3-26) insures the determination of true threats from decoys often requiring the integration of data from several sensors (Athans, 1987). In this regard supporting vision and military communication systems will satisfy this functional requirement.

Similarly, combat identification (Combat ID) is achieved by physically incorporating an identification mark on the vehicle or by using thermal reflection devices.

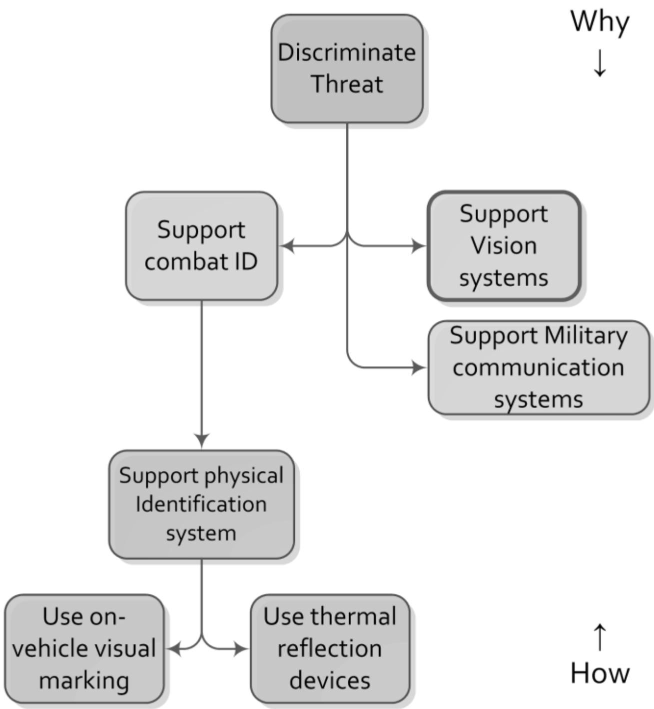


Figure 3-26 Discriminate threat function

3.4.1.3.6 Account for General Product Development Considerations

While the previous functions focused/concentrated on specialising the MATV vehicle as a defence and security product, the following functions are included to ensure that the final product meets the common standards and practises used during new product development process as shown in Figure 3-27.

The main considerations for the MATV development processes are;

1. Design for improved availability.
2. Facilitate disposal at the end of product lifecycle.
3. Account for design limitations and Constraints imposed by governmental and international accreditation agencies.

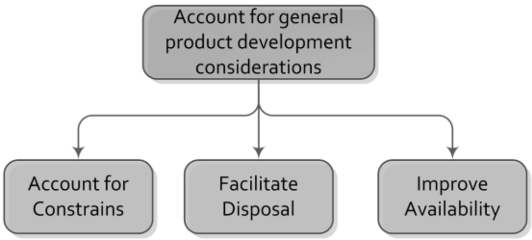


Figure 3-27 General product development considerations function

The availability means that the product is available when required for a given operation and that it will provide effective service during the course of that operation (Stapelberg and SpringerLink, 2009).

In addition, the following considerations are incorporated in the functional list to ensure that the MATV will provide high level of availability during its operational life as shown in Figure 3-28.

1. Account for general support, and training; both functions should allow for continued and professional follow up on the vehicle maintenance needs during its operational phase, leading to extended operational hours and reduced maintenance periods. Moreover, both functions can benefit from operational and maintenance documentations (manuals) which are generated during the product development process.
2. Support breakdown, and easy repair; both functions are intended to reduce the time for which the MATV is not operational due to system failure or breakdown, and hence act to improve the operation time (availability). This can be achieved by considering the maintenance requirements and repair aspects during the product design stage, such as designing quick release power pack mounts, detachable seats, and allowing for easy access to vehicle systems.
3. Account for towing recovery; this function allow the MATV to be quickly pulled out from an accident scene for maintenance, hence reducing the maintenance time and improving availability. This can be achieved by including emergency recovery packages such as, a self-recovery winch, recovery tool kit, and implementation of support for towing.

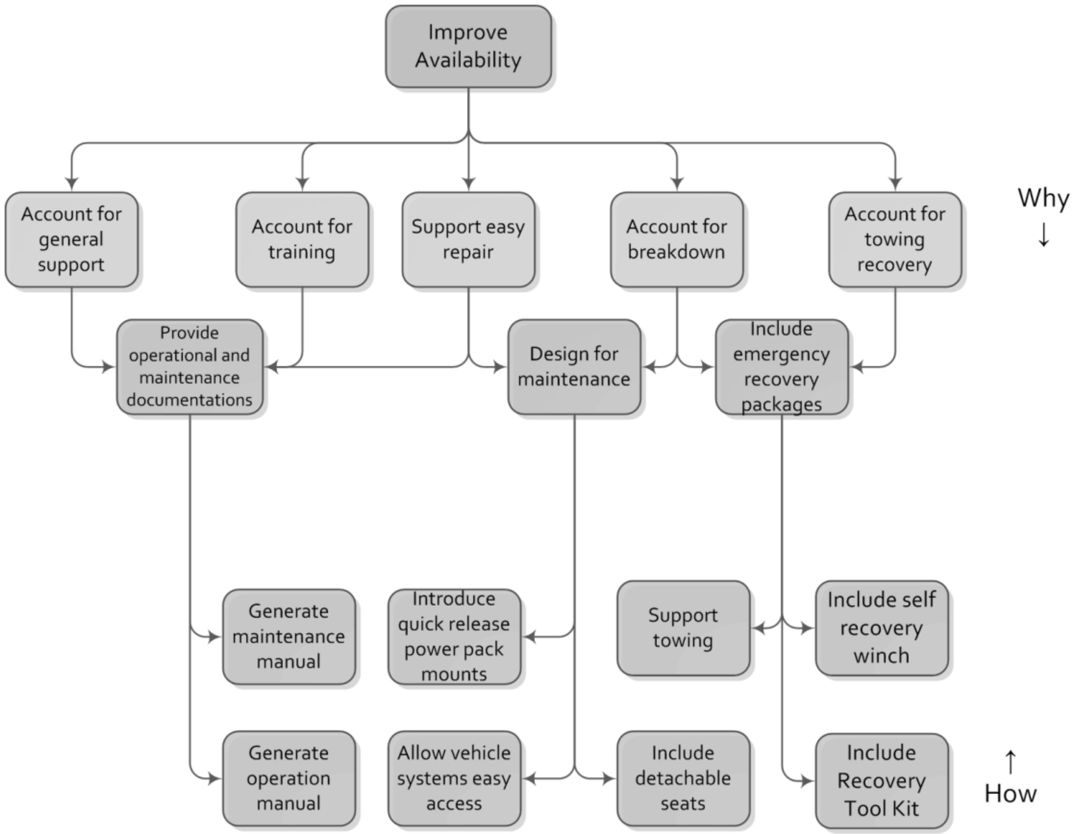


Figure 3-28 Improve availability function

The facilitate disposal function was included in the MATV functional tree due to its importance in allowing for controlled, documented and environmentally friendly product retirement at the end of the MATV lifecycle as shown in Figure 3-29.

This was achieved by introducing two sub-functions, including account for environmental impact and security. Together, these functions allowed compatibility with both environmental regulations and military security requirements.

The environment impact sub-function is best achieved during the early deign stages as 80% of the environmental destruction made by products is recognised after completing 20% of the design tasks (Otto and Wood, 2001).

The main consideration at this stage is to incorporate design concerns regarding the product's end of life disassembly, remanufacturing, recyclability and to minimise material usage for future upgrades.

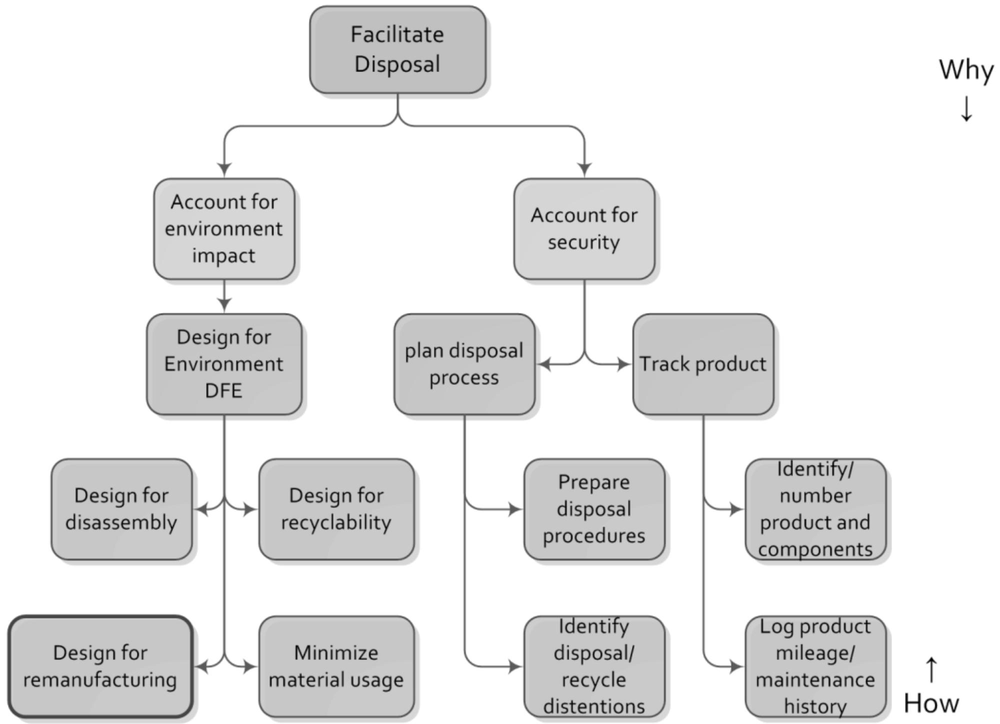


Figure 3-29 Facilitate disposal function

The security sub-function was achieved by planning the disposal process, including disposal procedures, and identifying disposal/recycle destinations, and by tracking the product records in terms of maintenance/replacement, mileage history, and identifying/numbering product and components.

The last function within the general product development is to “account for constraints”, which included requirements and regulations imposed by governmental and international accreditation agencies.

As shown in Figure 3-30, this function consists of following three sub-functions:

1. Account for legislations
2. Account for human factor integration
3. Account for safety

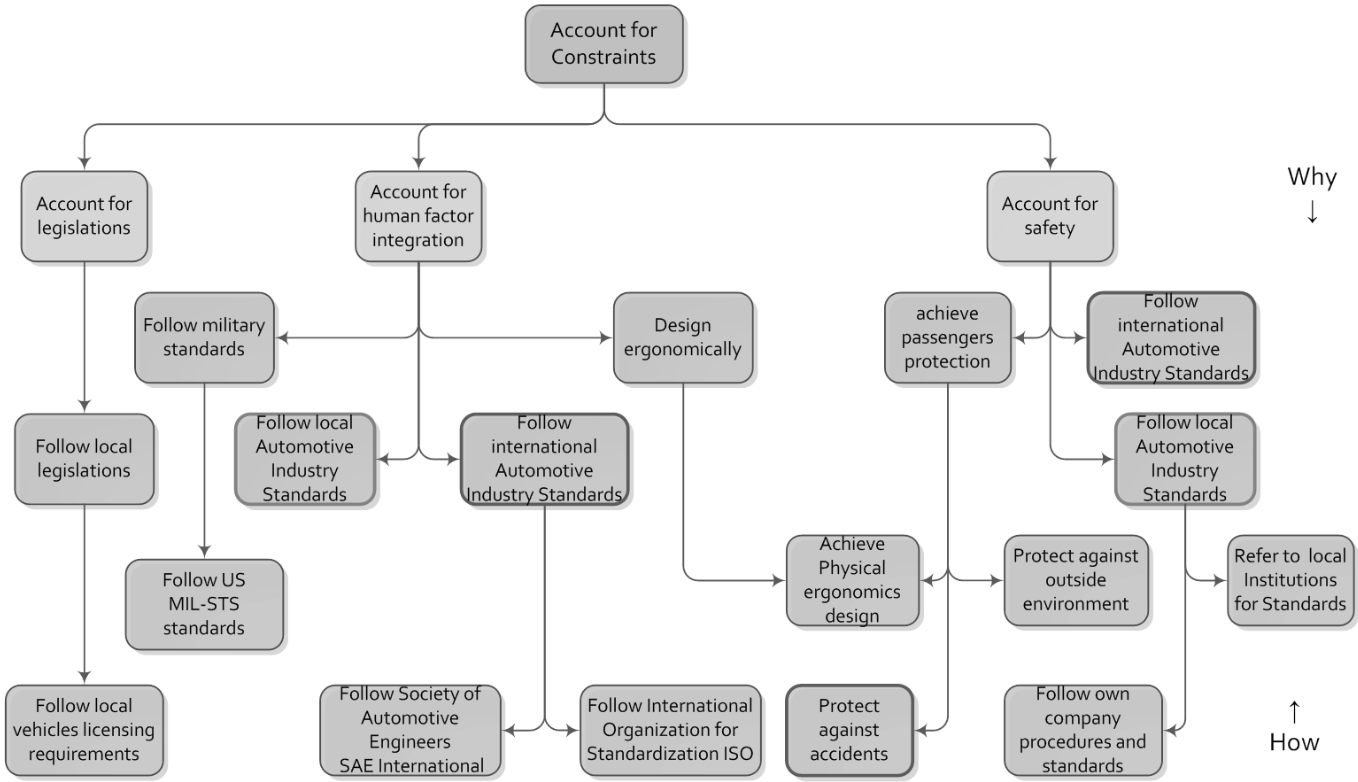


Figure 3-30 "Account for constraints" function

The "account for legislations" sub-function is mainly concerned with legislations imposed by local governmental agencies including vehicle licensing requirements such as allowed emissions, noise levels, weight and size limits.

The second sub-function "account for human factor integration" is an important functionality for the driver and crew compartment design as it was necessary to consider their physical, physiological, biomechanical, and psychological capabilities, while assuring their safety, health, and wellbeing (Fernandez, 1995).

Furthermore, this function was achieved by considering the aspects mentioned above within the design process and by following the main standards in the field of ergonomics including those of the international and local automotive industries such as the International Organisation for Standardisation (ISO), the Society of Automotive Engineers (SAE), the local standardisation institution and own company procedures and standards. In addition, the military standards concerning ergonomics are included in the functional list, such as the US MIL-STS standards.

The final sub-function “Account for safety” was also considered essential for protecting crew member’s lives during operation. Moreover, this function was achieved through implementing safety measures suggested by international and local automotive industry standards. This was one through direct design of protective structures and methodologies such as physical ergonomics deign for long term operation safety and passive protection against outside environment and crash accidents.

3.4.2 Product Architecture

The strategy of platform-based product family design has been utilised by an increasing numbers of manufacturers. This is due to its benefits in terms of enhancing the extent of customer satisfaction through offering a wide range of variety, while maintaining high levels of efficiency, effectiveness, and reduced cost (Liu et al., 2010).

Moreover, based on the results of the completive analysis and functional modelling stages, a platform deign has been adopted for the MATV for the above mentioned benefits, and to satisfy these results.

In this regard, modular product architecture has been developed, due to its importance in achieving the MATV platform design (Liu et al., 2010).

3.4.2.1 MATV Modular Design

Based on the clustering method for generating a modular design (described in section 2.6.5), the following four stages have been implemented for achieving the desired MATV modular design:

Stage 1: Functional Structure

This stage was mainly for achieving a functional structure relating to the MATV; in this regard, section 3.4.1, including the results presented in section 4.3.1, was used to accomplish this level.

Stage 2: Clustering

For this stage, nine categories have been selected in order to cluster the basic functions generated in section 4.3.1.

These categories cover the main systems and procedures for the development of the MATV as follows;

1. Structure
2. Electric\Electronic systems
3. Powertrain
4. Steering system
5. Break system
6. Protection
7. Communication system
8. Accessories
9. Documentation and procedures

By analysing and categorising each basic function, nine tables were generated for the clustered functions of MATV vehicle, in this regard; Table 3-36 shows the structure category. For reference, the remaining tables (Table E-1 to Table E-8) are presented in Appendix E.

Table 3-36 Structure category

No.	Basic function description	No.	Basic function description
1	Integrate imbedded hooks	16	Use tubular space frame
2	Use foldable structural components	17	Use high strength materials
3	Use lightweight structure	18	Fix lose components
4	Reduce sub-systems overall weight	19	Use high strength Joints
5	Improve power-weight ratio	20	Allocate space\supporting structure for future hardware installation
6	Reduce gradient resistance	21	Insulate engine compartment
7	Reduce aerodynamic resistance	22	Use standard components
8	Package heavy component	23	Include maintenance hatches
9	Design low centre of gravity	24	Use recyclable materials
10	Elevate exhaust outlet	25	Reduce product materials
11	Elevate air intakes	26	Reuse/reduce packaging materials
12	Increase ramp angle	27	Reduce materials for production
13	Increase approach angle	28	locate controls ergonomically
14	Increase departure angle	29	support ergonomically seating
15	Setup for urban area		

Stage 3: Rough Geometric Layout

As mentioned in section 2.6.5, this stage consists of two steps; the creation of product architecture hierarchy, and then the translation to 2D or 3D sketches of the product layout.

For the first step, the clustered basic functions were reflected in the component architecture hierarchy as shown in Figure 3-31. Moreover, the documentation and procedures category was not included in the hierarchy due to its nature; however, it is mainly included as guidance in the detailed design stage of the MATV, which is not covered in this research.

The second step included an illustrative 3D rendering of the MATV platform based on the previously developed component architecture hierarchy. In that regard, the 3D renderings aimed to demonstrate and suggest the main systems layouts of the MATV product, something which will help in later stages to generate different concepts of the same product.

The illustrative rendering shown in Figure 3-32, represent one option of packaging the main systems of the MATV, which was in this case a mid-engine layout (more 3D renderings are given in Appendix E). Although other layouts can be generated, the presented layout is based on the proven layout of the first generation MATV.

Although both generations share the same layout, the new MATV generation will have an improved structure in terms of rigidity, weight, and customisation as part of the modularity features of the vehicle.

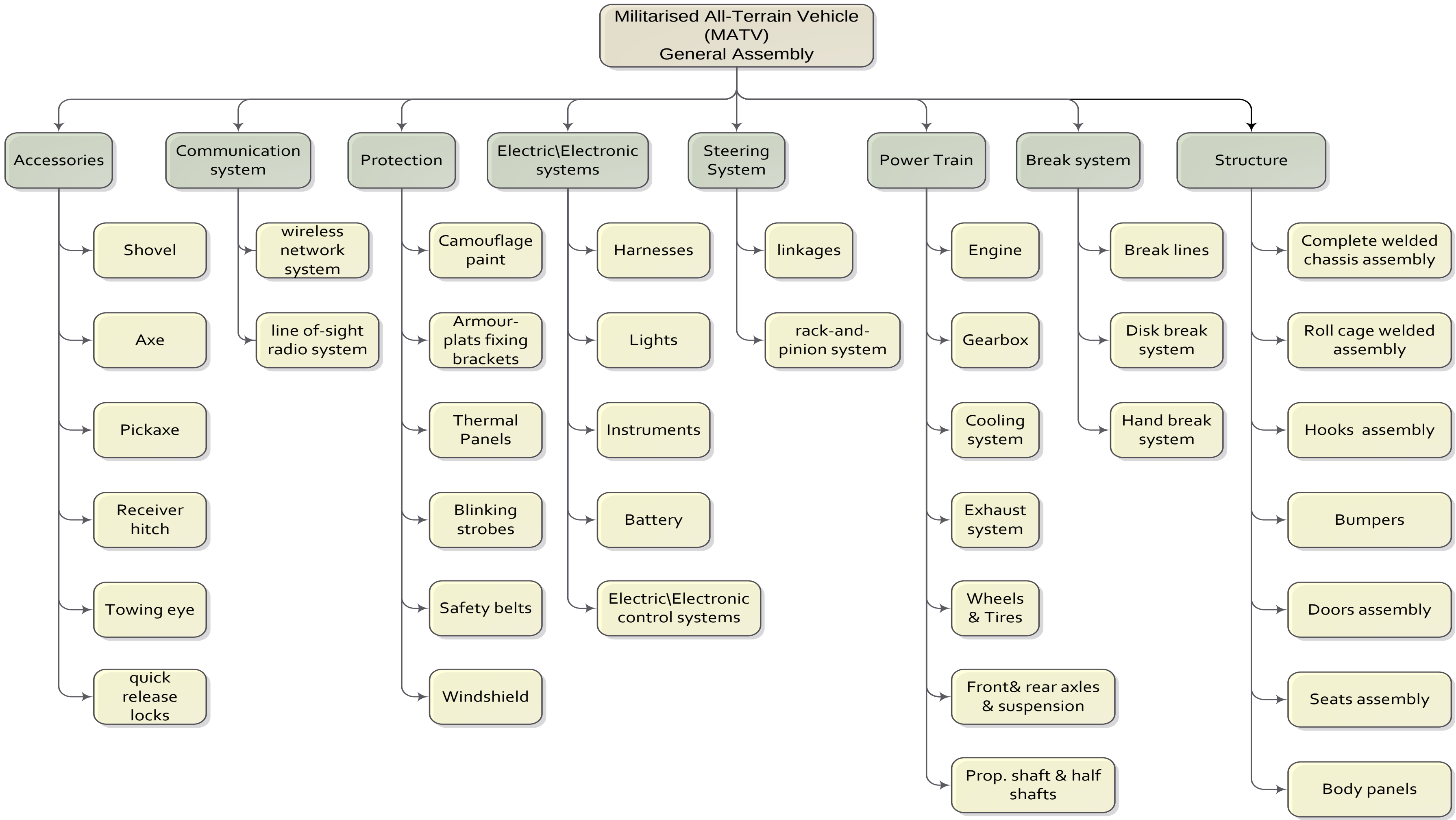


Figure 3-31 MATV component hierarchy

Structure

Powertrain, steering system, and break system

MATV Rough Geometric Layout

Figure 3-32 Illustration of MATV main systems layouts

Stage 4: Interaction Analysis

Due to the complexity of the MATV complete system, and time limitation, it was not possible to perform a full interaction analysis between all modules of the vehicle within the scope of this research.

Instead, a sample analysis was performed to demonstrate the concept of interaction analysis, and to set the stage for future detailed work.

In this regard, the MATV powertrain was selected for the system level design analyse performed in this section.

As illustrated in stage 4 within section 2.6.5, and with reference to the powertrain component hierarchy shown in Figure 3-31, a boundary diagram was generated in order to identify the powertrain system inputs and outputs (see Figure 3-33).

The generated diagram indicates thirteen internal and five external sub-systems within the powertrain main system; moreover, as an example, the driver has multiple inputs to the system through four controllers, such as the accelerator pedal, and the 4x4 selector.

The next step was to document the interface analysis through the Interface Matrix (IM) as shown in Figure 3-34. In this regard, exchange type annotations were assigned to each pair of interfacing subsystems within the powertrain. For example, the matrix showed that at the interface between the “transmission” and the “transfer case” there is a physical ‘P’ relation (the transfer case is directly bolted on the transmission, which requires high geometrical tolerances between the mating faces), and also an energy exchange (mechanical energy ‘E’ from the transmission to the transfer case, which requires strength matching analysis for the internal gears, shafts, and all affected components of the two sub-systems).

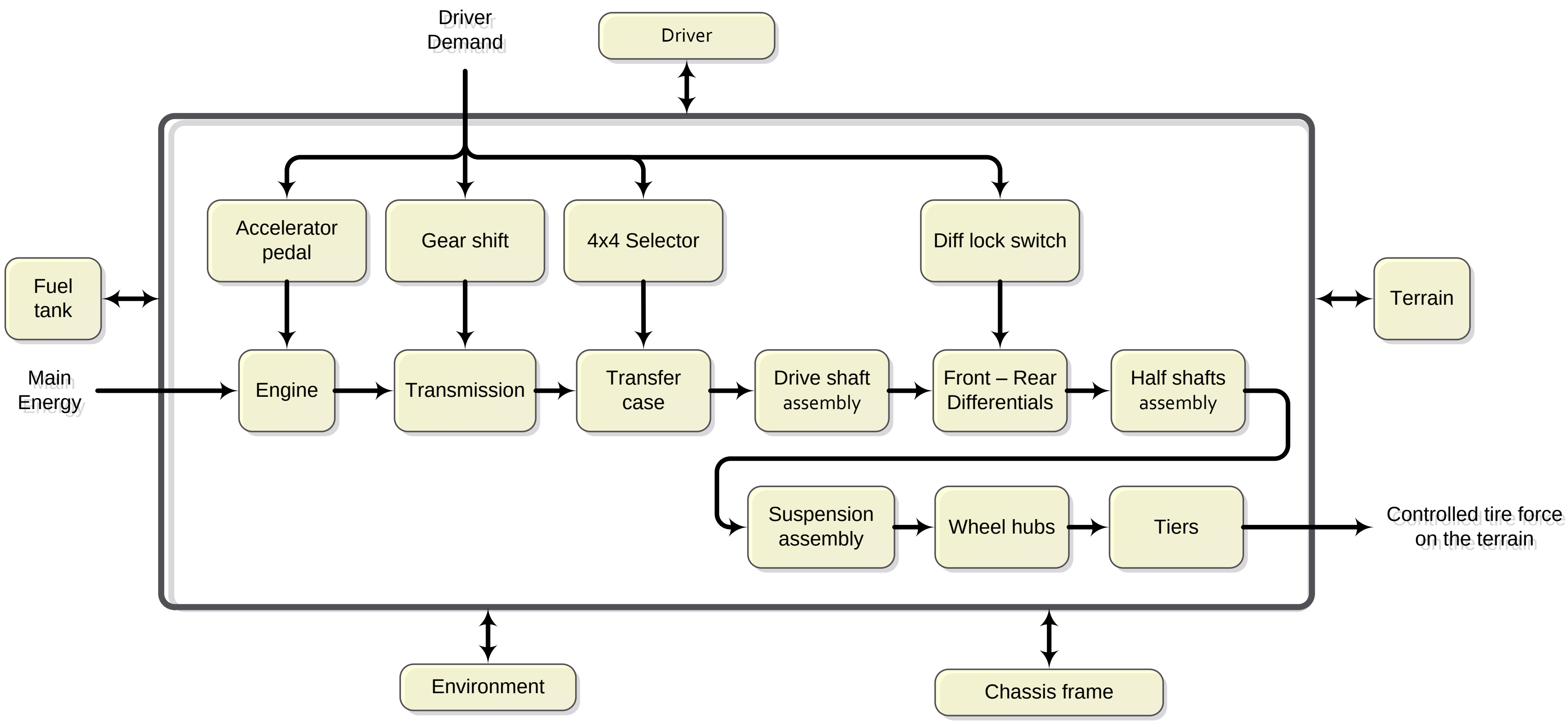


Figure 3-33 System boundary diagram for MATV powertrain

INTERFACE MATRIX		Internal Interfaces																										External Interfaces									
		A		B		C		D		E		F		J		H		I		J		K		L		M		E1		E2		E3		E4		E5	
		Engine		Accelerator pedal		Transmission		Gear shift		Transfer case		4x4 selector		Drive shaft Assembly		Front – Rear differentials		Diff lock switch		Half shaft Assembly		Suspension assembly		Wheel hubs		Tiers		Fuel tank		Driver		Environment		Chassis frame		Terrain	
1	Engine					P	E																						E			P	E	P	E		
				I		I																							M				M				
2	Accelerator pedal		I																											P	E	P	E	P	E		
																												I									
3	Transmission	P	E					P	E	P	E																					P	E	P	E		
		I						I																									M				
4	Gear shift					P	E																							P	E	P	E	P	E		
						I																															
5	Transfer case					P	E					P	E	P	E																	P	E	P	E		
												I																					M				
6	4x4 Selector									P	E																			P	E	P	E	P	E		
										I																											
7	Drive shaft Assembly									P	E					P	E					P	E									P	E	P	E		
																																	M				
8	Front – Rear differentials													P	E			P	E	P	E	P	E									P	E	P	E		
																		I															M				
9	Diff lock switch															P	E													P	E	P	E	P	E		
																I																	M				
10	Half shafts Assembly															P	E					P	E	P	E							P	E	P	E		
11	Suspension assembly													P	E	P	E			P	E			P	E	P	E			P	E	P	E	P	E	P	E
																																	M				
12	Wheel hubs																			P	E	P	E			P	E					P	E	P	E		
																																	M				
13	Tiers																					P	E	P	E							P	E	P	E	P	E
																																	M		M		

Figure 3-34 Interface matrix for MATV powertrain

Where; (P) Physical, (E) Energy, (I) Information, and (M) Material

3.5 Summary

The implementation phase of this study presented a step by step customer focused approach within the preliminary product development stage to realise a concept which meets the operational needs. .

The study has utilised AHP, Kano, QFD, and functional tree to develop a product which not only satisfies customer requirements but exceeds his delight and performance expectation. .

In the earlier section, technical specifications were derived using the QFD analysis. Similarly in this chapter the design drivers method was used to establish the physical architecture and functional model which assisted in verifying the QFD analysis by reverse processing 'HOWS' and 'WHYS'. In other words, design drivers method was coupled with QFD analysis to ensure realistic specifications are set. The application of the novel dual mode QFD coupled with the Design Drivers method is an original and unique approach reported in the current work.

In addition, this chapter used a systematic approach for generating a comprehensive functional tree and a 3D architecture model.

4 RESULTS

Following the product development process, the results obtained during each phase are used as an input for the subsequent phase.

4.1 Chapter Roadmap

In the following sections, the preliminary result in the form of charts and tables obtained using customer survey, questionnaires, Kano and AHP priority matrix are presented to analyse characterised as each stage of the development process. . The aim is to extract the required data and values for achieving the desired MATV product – with the ultimate goal of eventually demonstrating the validity of the research methodologies presented in this study. For example customer survey, questionnaire and self-assigned values assisted in identifying the customer thinking and important requirements. This data was used in AHP process to priorities the requirements. Similarly same data was used to identify the nature of the requirement (one dimensional, delightful or must be). Data obtained from this analysis was utilised in establishing the QFD matrix.

Finally, the overall results generated by the implementation phase which covers functional and architectural modelling, were listed and compared with the current specifications of the 1st generation MATV; this comparison allowed this study to demonstrate that the proposed improvements in the 2nd generation over the 1st generation MATV will result in a finer system.

4.2 Understand the Opportunity Phase

The opportunity phase allows identification of highly anticipated customer requirements. Furthermore, it identifies the key correlated characteristics of the product under consideration using the dual mode Kano-AHP process and the dual mode QFD analyses as outlined previously in chapter 3.

4.2.1 Customer Need Analysis

In this phase, the results are analysed in order to elect the most important user requirements from both Kano and AHP modes.

4.2.1.1 Analytic Hierarchy Process AHP Mode

Based on the global importance rating for each CR within level II-A in Hierarchy I, it was possible to compare all 41 CRs against each other, while taking in to consideration the effect of the relative importance of level I CRs.

1. Level II-A CRs Global Importance Summary

The final global importance values of level II-A CRs are summarised in Table 4-1.

Table 4-1 Level II-A CRs global importance summary

Level II-A CRs	Global Importance %	Ranking
Max Speed	3.0%	12
Slop climbing	3.5%	5
Obstacles crossing	3.0%	11
Natural terrains interaction	2.4%	23
Manoeuvrability	2.6%	16
Cruising range	2.0%	29
Visibility	3.8%	4
Ride comfort	3.1%	10
Automation	2.1%	26

Protection from outside	3.5%	6
Reduced Footprint	3.2%	9
Ballistic Protection	3.2%	8
Rollover Protection	4.1%	2
Light-Medium weight weapons	4.9%	1
Medium-Heavy weight weapons	2.5%	19
Precision munitions	3.5%	7
Parachute deployment	2.8%	14
Transportability by C-130	2.4%	22
Transportability by trailer	2.3%	24
Compatibility with Airlift by helicopters	2.3%	25
Overall size limits	2.4%	21
Weight limit	2.0%	28
Clearance angles	1.9%	30
Aesthetic Look	1.0%	41
Reconnaissance	1.7%	31
Fighting vehicle	1.3%	34
Troup carrier	1.1%	39
Unmanned	1.0%	40
Logistics	1.2%	36
Command and Control	1.2%	38
Number of crew members	2.6%	17
Payload	2.9%	13
Towing load	1.3%	35
Recoil shock absorption	1.7%	32

Level II-A Customer	Global Importance %	Ranking
Diesel engine	4.0%	3
Petrol engine	2.1%	27
Electrical motor engine	1.2%	37
Hybrid system	1.5%	33
VHF/ UHF radios	2.6%	18
2 way, audio and video data	2.7%	15
GPS	2.5%	20

2. CRs Selection

For the purpose of this study a maximum of 25 CRs were selected out of the 41CRs analysed during the AHP. This selection was undertaken in order to avoid excessive size of the resultant matrix and consequently produce a manageable AHP based QFD (QFD Online, 2008) to be used in the competitive analysis section.

By filtering the highest ranked CRs in Table 4-1, a final list of 25 CRs are selected as shown in Table 4-2.

Table 4-2 Final 25 selected CRs

Customer Requirements	Global Importance %	Ranking
Light-Medium weight weapons	4.9%	1
Rollover protection	4.1%	2
Diesel engine	4.0%	3
Visibility	3.8%	4
Slop climbing	3.5%	5

Customer Requirements	Global Importance %	Ranking
Protection from outside environment	3.5%	6
Precision munitions	3.5%	7
Ballistic protection	3.2%	8
Reduced footprint	3.2%	9
Ride comfort	3.1%	10
Obstacles crossing	3.0%	11
Max speed	3.0%	12
Payload	3.0%	13
Parachute deployment	2.8%	14
2 way, audio and video data	2.7%	15
Manoeuvrability	2.6%	16
Number of crew members	2.6%	17
VHF/ UHF Radios	2.6%	18
Medium-Heavy weight weapons	2.5%	19
GPS	2.5%	20
Overall size limits	2.4%	21
Transportability by C-130	2.4%	22
Natural terrains interaction	2.4%	23
Transportability by trailer	2.3%	24
Compatibility with airlift by helicopters	2.3%	25

4.2.1.2 Kano Model Mode

Based on the summary of answer tables, and from the analytical process described in section 3.1.1.2.4, two diagrams have been generated, namely the Customer Satisfaction (CS) coefficient diagram and the self-stated importance ranking.

1. CS-Coefficient Diagram

The results shown in Table 3-21 have been plotted to generate the CS-coefficient diagram shown in Figure 4-1.

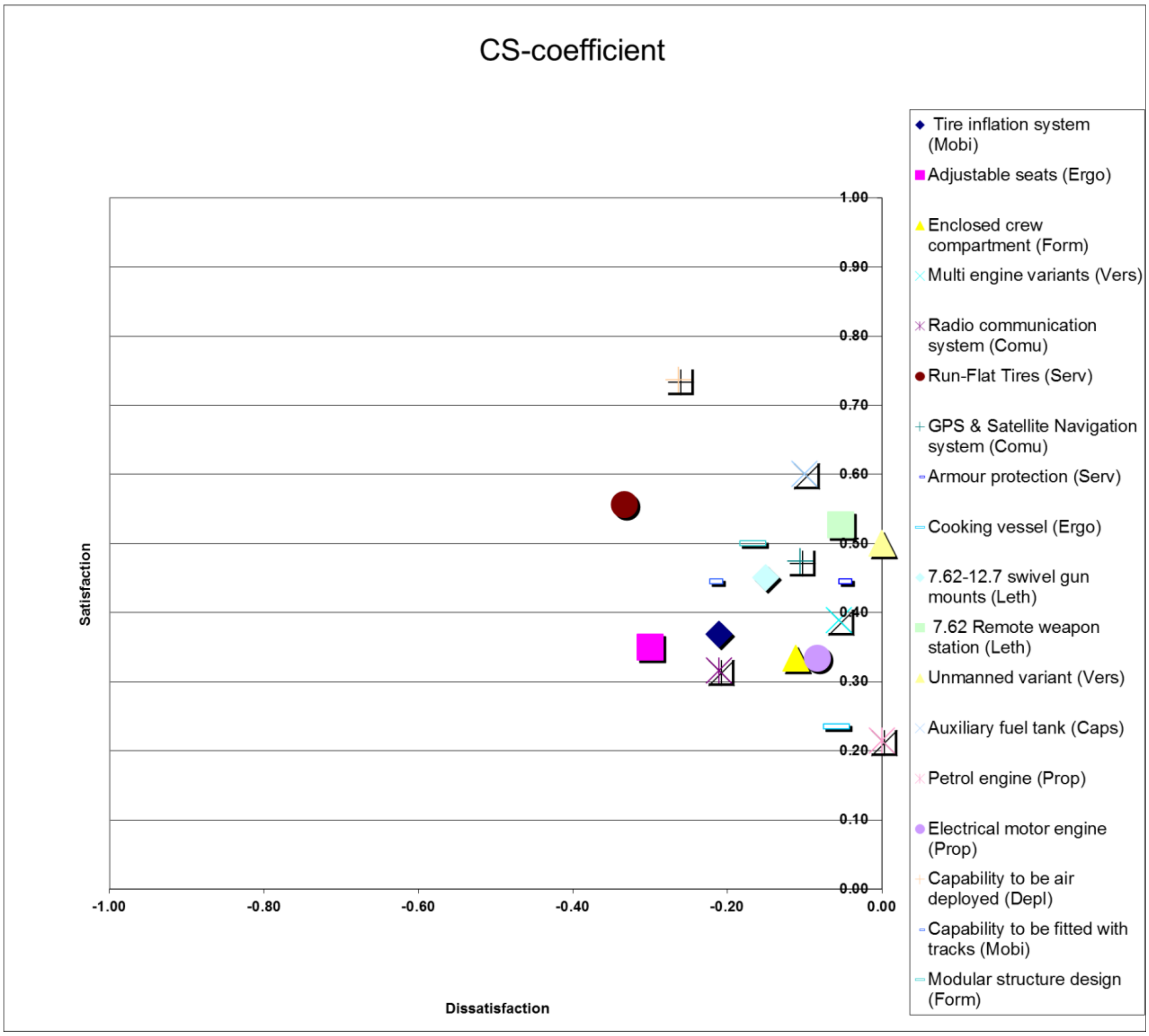


Figure 4-1 CS coefficient

With reference to section 2.3.4.4, this plot shows a number of customer requirements that have the highest impact on customer satisfaction once fulfilled, including the capability to be air deployed, auxiliary fuel tank, run-flat tires and the desire to have a 7.62-mm Remote weapon station.

However, at the same time, two of the customer requirements have the highest impact on CS if not fulfilled. These requirements are the capability to be air deployed and run-flat tires. The adjustable seats requirement also exhibits a high level of customer dissatisfaction if not incorporated. However, the CS-coefficient plot suggests that it has low CS once fulfilled.

On the other hand, another group of requirements show a very low level of dissatisfaction if not fulfilled, as well as a low level of satisfaction once fulfilled. These requirements include; petrol engine, cooking vessel, electrical motor engine, enclosed crew compartment, multi-engine variants, armour protection, and provision of an unmanned variant.

2. Self-Stated Importance Ranking

The self-stated importance values collected from the Kano questionnaires are plotted in Figure 4-2. This figure was designed to aid visualisation of the requirements with high importance values based on customer opinions. In the next step, these values have been combined with CS values as shown in Table 4-3. By doing so, a more holistic view is achieved to assist in the categorisation and selection of the final customer requirements (CRs) to be used as an input to the Kano-based QFD.

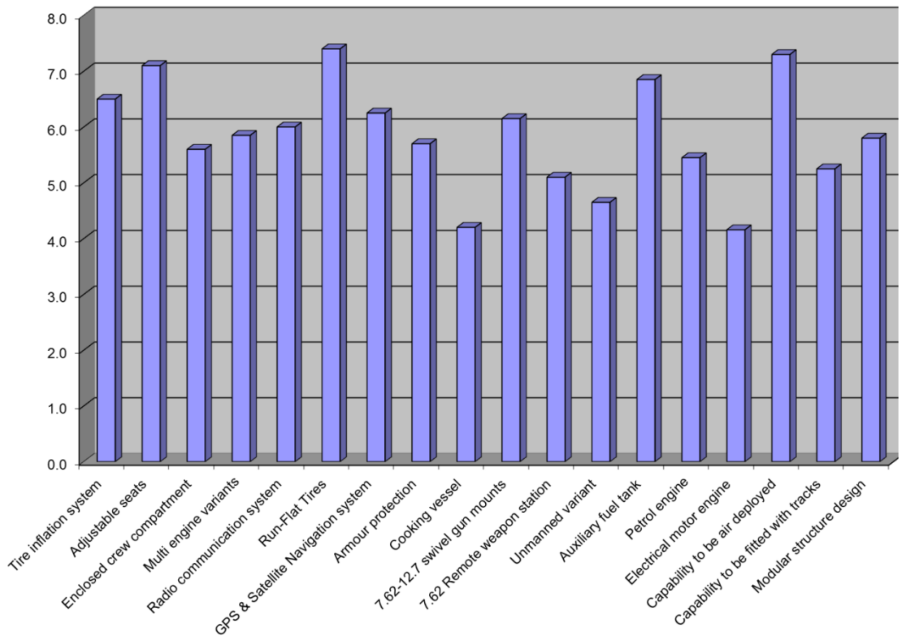


Figure 4-2 Self-Stated importance ranking

3. Results Evaluation and Interpretation

In this stage, the most significant and influential requirements are selected for the QFD analysis. For the Kano model, the priority for selecting the requirements is based on the following categories:

1. Must-be (M).
2. One-Dimensional (O).
3. Attractive (A).
4. Indifferent (I).

However, as part of the dual mode approach, and as mentioned in section 3.3.2.1, the type of CR's which were used in the Kano questionnaires are predominantly accessories and complimentary CR's as opposed to the basic CR's which were used in AHP questionnaires.

Therefore, the results generated from Kano model are expected to fall within the One-Dimensional, Attractive and Indifferent categories (something which will be shown by the end of this section).

For the categorisation and selection process, Table 4-3 was generated which combined the CS plot shown in Figure 4-1, the tabulation of questionnaire responses, the functional and dysfunctional properties as shown in Table 3-20 and the self-stated importance rankings as shown in Figure 4-2.

A selection criterion was then developed to ensure a systematic approach to acquire objective results. The first step was to categorise the CRs according to the Kano model, and then to select 10 CRs according to the category priority obtained using equation (4-1**)**.

The categorisation and selection process employed is summarised as follows:

- First the categorisation action is based on frequency. In other words referring to frequency values with a difference > 5% between categories as shown in Table 4-3. The category with the highest value is assigned to the adjacent CR.

- For CRs with frequency values with a 5% difference between the categories, self-stated importance ≥ the mean value (5.8), extent of satisfaction ≥ 0.35 and extent of dissatisfaction ≥ 0.10, the following evaluation rule is used (Sauerwein et al., 1996):

$$M > O > A > I \tag{4-1}$$

  Where M is must-be, O is One-Dimensional, A is Attractive, and I refers to Indifferent requirements.

  The reason behind this categorisation criterion is to introduce more logic to the results, particularly in the case where attractive and Indifferent categories occur with close or equal frequency values.

- For CRs with an Indifferent category and a high self-importance value ≥ 6.5, the relevant CRs were selected to complete the final 10 CRs list.

The final results of the selected CRs are shown in Table 4-4.

Table 4-3 Combined CS and self-importance categorisation and selection table

Combined CS and Self-importance selection table															
Customer Requirement Questions			Attractive	One-dimensionsal	Must-be	Indifferent	Reverse	Questionable	Total	Self-stated Importance	Extent of Satisfaction	Extent of Dissatisfaction	Kano Category	Final ranking
Q01	Tire inflation system (Mobi)	Responses	4	3	1	11	1	0	20	6.50	0.37	-0.21	I	10
		Percentage	20%	15%	5%	55%	5%	0%	100%					
Q02	Adjustable seats (Ergo)	Responses	6	1	5	8	0	0	20	7.10	0.35	-0.30	I	9
		Percentage	30%	5%	25%	40%	0%	0%	100%					
Q03	Enclosed crew compartment (Form)	Responses	4	2	0	12	2	0	20	5.60	0.33	-0.11	I	14
		Percentage	20%	10%	0%	60%	10%	0%	100%					
Q04	Multi engine variants (Vers)	Responses	6	1	0	11	2	0	20	5.85	0.39	-0.06	I	12
		Percentage	30%	5%	0%	55%	10%	0%	100%					
Q05	Radio communication system (Comu)	Responses	5	1	3	10	1	0	20	6.00	0.32	-0.21	I	11
		Percentage	25%	5%	15%	50%	5%	0%	100%					
Q06	Run-Flat Tires (Serv)	Responses	7	3	3	5	2	0	20	7.40	0.56	-0.33	A	1
		Percentage	35%	15%	15%	25%	10%	0%	100%					
Q07	GPS & Satellite Navigation system (Comu)	Responses	8	1	1	9	1	0	20	6.25	0.47	-0.11	A	4
		Percentage	40%	5%	5%	45%	5%	0%	100%					
Q08	Armour protection (Serv)	Responses	8	0	1	9	1	1	20	5.70	0.44	-0.06	I	13
		Percentage	40%	0%	5%	45%	5%	5%	100%					
Q09	Cooking vessel (Ergo)	Responses	4	0	1	12	I	0	21	4.20	0.24	-0.06	I	17
		Percentage	19%	0%	5%	57%	19%	0%	100%					
Q10	7.62-12.7 swivel gun mounts (Leth)	Responses	8	1	2	9	0	0	20	6.15	0.45	-0.15	A	5
		Percentage	40%	5%	10%	45%	0%	0%	100%					
Q11	7.62 Remote weapon station (Leth)	Responses	9	1	0	9	1	0	20	5.10	0.53	-0.05	A	7
		Percentage	45%	5%	0%	45%	5%	0%	100%					
Q12	Unmanned variant (Vers)	Responses	8	0	0	8	4	0	20	4.65	0.50	0.00	A	8
		Percentage	40%	0%	0%	40%	20%	0%	100%					
Q13	Auxiliary fuel tank (Caps)	Responses	11	1	1	7	0	0	20	6.85	0.60	-0.10	A	3
		Percentage	55%	5%	5%	35%	0%	0%	100%					
Q14	Petrol engine (Prop)	Responses	3	0	0	11	5	1	20	5.45	0.21	0.00	I	15
		Percentage	15%	0%	0%	55%	25%	5%	100%					
Q15	Electrical motor engine (Prop)	Responses	3	1	0	8	8	0	20	4.16	0.33	-0.08	I	18
		Percentage	15%	5%	0%	40%	40%	0%	100%					
Q16	Capability to be air deployed (Depl)	Responses	11	3	2	3	1	0	20	7.30	0.74	-0.26	A	2
		Percentage	55%	15%	10%	15%	5%	0%	100%					
Q17	Capability to be fitted with tracks (Mobi)	Responses	5	3	1	9	2	0	20	5.25	0.44	-0.22	I	16
		Percentage	25%	0.15	5%	45%	10%	0%	100%					
Q18	Modular structure design (Form)	Responses	7	2	1	8	2	0	20	5.80	0.50	-0.17	A	6
		Percentage	35%	10%	5%	40%	10%	0%	100%					

Table 4-4 Final 10 selected customer requirements

Selected Customer Requirement	Kano Category	Ranking
Run-Flat Tires	A	1
Capability to be air deployed	A	2
Auxiliary fuel tank	A	3
GPS & Satellite Navigation system	A	4
7.62-12.7 swivel gun mounts	A	5
Modular structure design	A	6
7.62 Remote weapon station	A	7
Unmanned variant	A	8
Adjustable seats	I	9
Tire inflation system	I	10

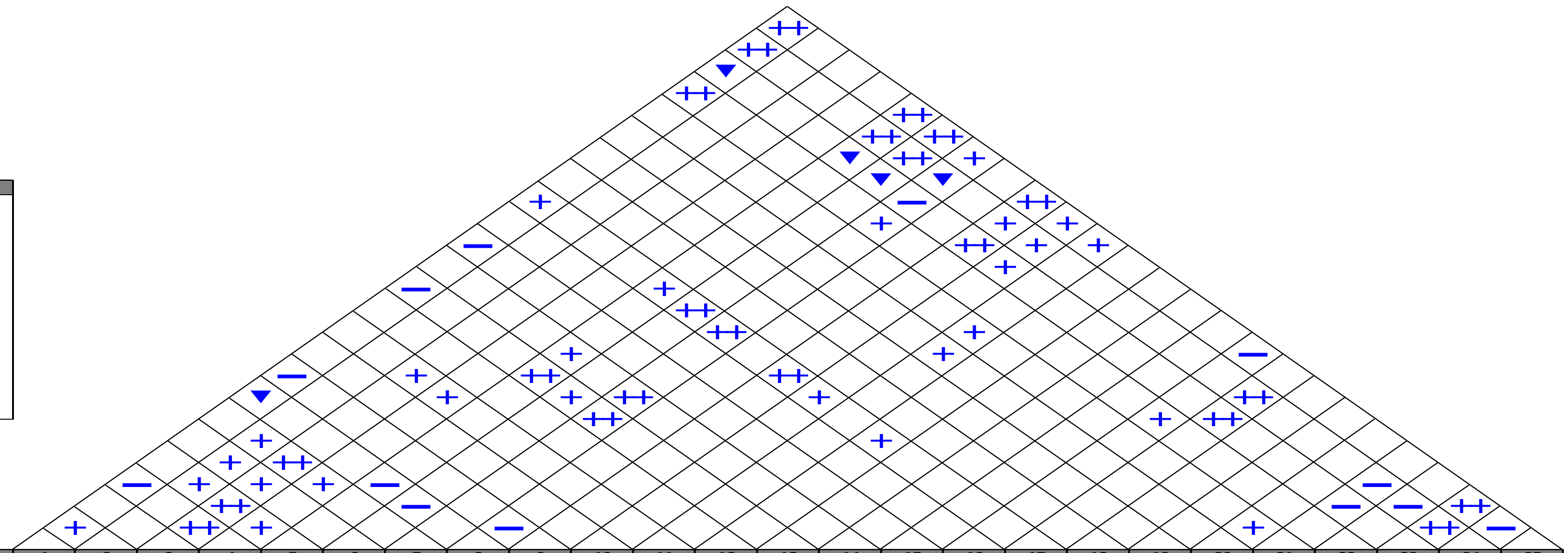
4.2.2 Competitive Analysis

In this phase, the final high-level engineering specifications with their target values for the MATV vehicle were identified based on the integrated dual mode QFD analysis. These specifications were generated by combining and comparing the target values results for both modes (Kano and AHP). The highest/best values covering both modes as described in section 3.3.2 were selected for further analysis.

4.2.2.1 Integrated Dual QFD

The final dual QFD results represented by the house of quality of each QFD mode are shown in Figure 4-3 for the AHP based QFD and Figure 4-4 for the Kano based QFD respectively.

Legend		
Θ	Strong Relationship	9
O	Moderate Relationship	3
▲	Weak Relationship	1
++	Strong Positive Correlation	
+	Positive Correlation	
—	Negative Correlation	
▼	Strong Negative Correlation	
▼	Objective Is To Minimize	
▲	Objective Is To Maximize	
x	Objective Is To Hit Target	



Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Our Company : 2nd Gen. ATV II	Competitor 1 :1st Gen. ATV I	Competitor 2: Polaris MRZR 2	Competitor 3: TOMCAR TM5	Competitor 4: JOHN DEERE M-Gator A2
				Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)	▲	▲	▲	▲	x	x	x	x	▲	x	▲	▼	x	x	x	▼	x	x	x	x	x	x	▲	▼	▲	Competitive Analysis (0=Worst, 5=Best)				
				Demanded Quality (a.k.a. "Customer Requirements" or "Whats") / Quality Characteristics (a.k.a. "Functional Requirements" or "Hows")	Top speed	Wheel Base \ Wheel Track	Clearance Angles (Approach, Departure, Ramp)	Ground Clearance	Climbing ability	Side Slop	Ditch crossing, Fording	Protection level	Cruising Range	Armament calibre	High capacity electrical alternator, High capacity battery	Turning Radius	4 wheel Drive System	Differential Lock	Windshield	Vehicle Noise Level	suspension system	High strength lifting hocks	High strength detachable/foldable crew and bed roll bars	Sights	Communication System & GPS Antenna	Transmission	Max Payload	Curb Weight	Engine power					
1	9	3.9	3.0	Max speed	Θ	▲						O					O		O	▲	O					Θ	Θ	Θ	Θ	3	2	5	4	2
2	9	4.7	3.5	Slop climbing		▲	O	O	Θ	Θ							Θ	O			O					Θ	O	Θ	Θ	4	4	4	4	4
3	9	4.0	3.0	Obstacles crossing		Θ	Θ	Θ	O	O	Θ					Θ	Θ	Θ			Θ					O	O	O	Θ	5	4	4	4	3
4	9	3.1	2.4	Natural Terrains Interaction	Θ	Θ	Θ	Θ									Θ	Θ			Θ					Θ	Θ	Θ	Θ	5	4	4	4	3
5	9	3.5	2.6	Manoeuvrability	Θ	Θ	Θ	Θ				O				Θ	Θ	Θ			Θ					Θ	Θ	Θ	Θ	5	4	4	4	3
6	9	3.4	2.5	Medium-Heavy w eight w eapons	O	O			O	O		O	Θ	Θ	Θ		O		Θ		Θ		Θ	Θ	O	O	Θ	Θ	Θ	4	3	0	0	0
7	9	5.1	3.8	Visibility		▲		O				O							Θ					Θ						4	4	4	4	4
8	9	4.1	3.1	Ride Comfort		O		O									O				Θ					O		O	O	3	3	3	3	3
9	9	4.6	3.5	Protection from outside environment				O				Θ							Θ				Θ							4	1	1	4	5
10	9	4.2	3.2	Reduced Footprint		▲													▲	Θ										3	1	2	2	2
11	9	4.2	3.2	Ballistic Protection								Θ		O					O											3	3	0	4	0
12	9	5.5	4.1	Rollover Protection		O																	Θ							4	4	4	4	4
13	9	6.4	4.9	Light-Medium w eight w eapons										Θ													Θ	O		4	4	4	4	4
14	9	4.6	3.5	Precision munitions										O	O									Θ	Θ		Θ	O		5	4	2	2	0
15	9	3.6	2.8	Parachute deployment		Θ															Θ	Θ						Θ		4	0	4	3	0
16	9	3.2	2.4	Transportability by C-130		Θ															O	Θ						Θ		4	3	4	4	3
17	9	3.0	2.3	Transportability by trailer		Θ															O	Θ						Θ		5	4	5	5	4
18	9	3.0	2.3	Compatibility w ith Airlift by helicopters		Θ															Θ	Θ						Θ		5	2	5	5	3
19	9	3.2	2.4	Overall size limits		Θ	Θ	Θ																						4	3	3	3	3
20	9	3.4	2.6	VHF/ UHF Radios											Θ								O				Θ	Θ		4	0	4	4	0
21	9	3.3	2.5	GPS											O								▲		Θ		Θ	▲		4	4	4	4	4
22	9	3.5	2.6	Number of crew members		Θ																		▲	Θ			Θ	O	4	4	4	4	4
23	9	3.9	2.9	Payload								Θ					O				Θ					Θ	Θ	Θ	Θ	4	2	3	4	5
24	9	5.3	4.0	Diesel Engine	Θ	O							Θ							Θ						O	O	Θ	Θ	4	4	4	4	4
25	9	3.5	2.7	2 w ay, audio and video data											Θ									Θ	Θ		▲	▲		3	0	3	3	3
				Target or Limit Value	75 Km/h	2350mm\1600mm	75 deg, 65 deg, 18 deg	350mm	60%	40%	500mm, 500mm	soft skin-B6 (based of variant type)	500Km	7.62mm-12.7 (based of variant type)	300+ watt, 12V approx. 15 Ah	5 m	yes	yes	yes	75 dB	Independent double wishbone	yes	yes based of variant type)	yes based of variant type)	yes based of variant type)	CVT	500 kg	700 Kg	60 hp					
				Difficulty (0=Easy to Accomplish, 10=Extremely Difficult)	7	7	4	7	2	1	4	8	7	6	5	8	2	2	1	9	6	4	7	5	5	6	8	9	8					
				Max Relationship Value in Column	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9					
				Weight / Importance	152.1	343.4	138.0	179.2	64.0	64.0	35.9	161.7	77.5	114.3	116.3	67.2	182.8	109.3	145.9	88.8	301.2	115.9	134.5	151.8	143.6	221.5	364.5	491.1	307.4					
				Relative Weight	3.6	8.0	3.2	4.2	1.5	1.5	0.8	3.8	1.8	2.7	2.7	1.6	4.3	2.6	3.4	2.1	7.1	2.7	3.1	3.6	3.4	5.2	8.5	11.5	7.2					

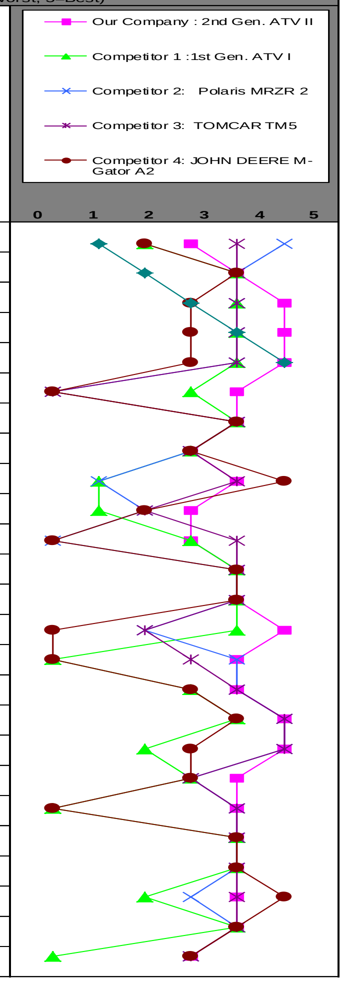
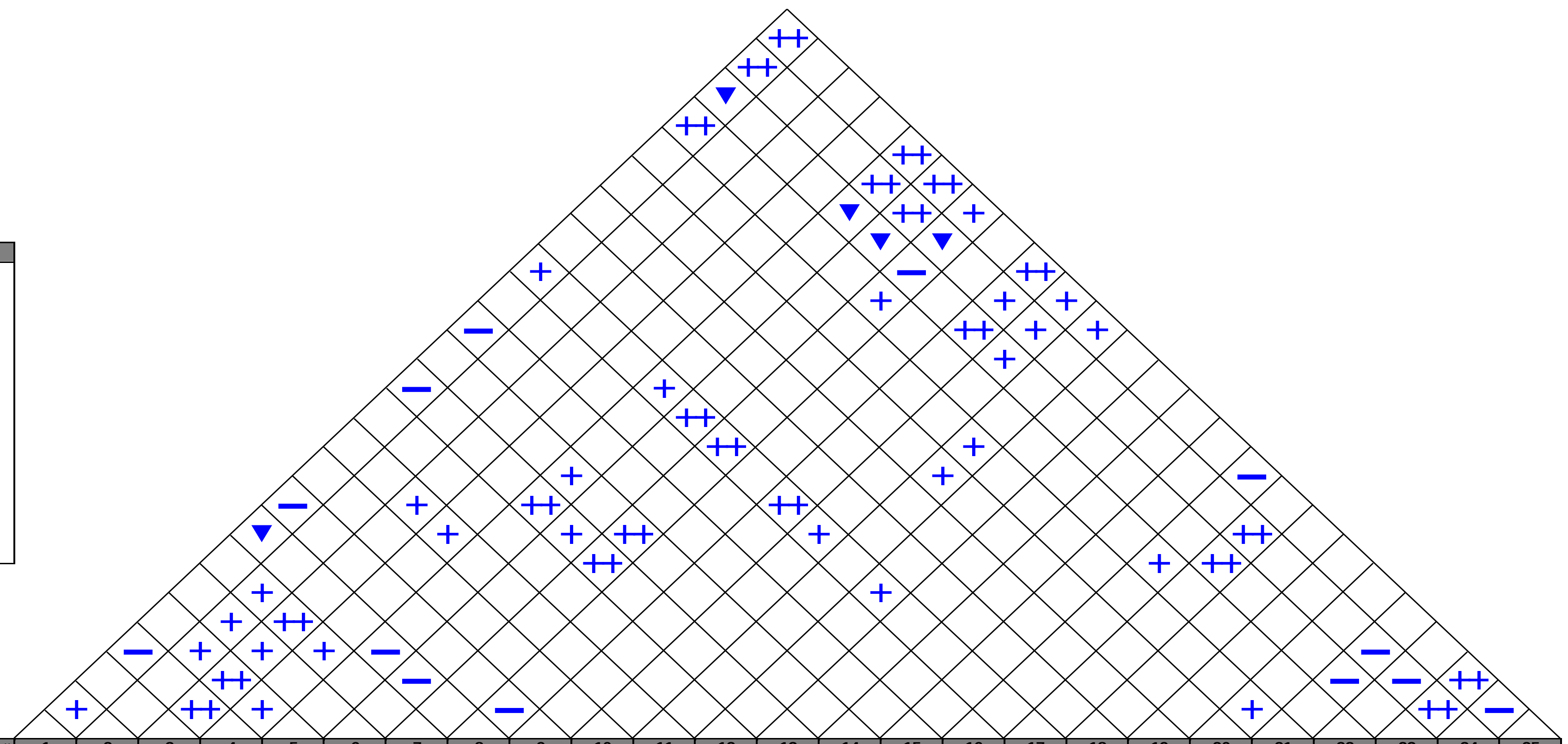


Figure 4-3 House of Quality, AHP based QFD

Legend		
Θ	Strong Relationship	9
O	Moderate Relationship	3
▲	Weak Relationship	1
++	Strong Positive Correlation	
+	Positive Correlation	
−	Negative Correlation	
▼	Strong Negative Correlation	
▼	Objective Is To Minimize	
▲	Objective Is To Maximize	
x	Objective Is To Hit Target	



Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Column #	1	2	3	4	5	6	7	8	9	10	11	12
				Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)	x	▲	▲	▲	x	x	x	x	▲	x	x	▼
				Quality Characteristics (a.k.a. "Functional Requirements" or "How s") / Demanded Quality (a.k.a. "Customer Requirements" or "Whats")	Top speed	Wheel Base \ Wheel Track	Clearance Angles (Approach, Departure, Ramp)	Ground Clearance	Climbing ability	Side Slop	Ditch crossing, Fording	Protection level	Cruising Range	Armament calibre	High capacity electrical alternator, High capacity battery,	Turning Radius
1	9	11.7	7.4	Run-Flat Tires	Θ	▲		O	O	O		Θ	O			
2	9	11.6	7.3	Capability to be air deployed		Θ	O	Θ								
3	9	10.9	6.9	Auxiliary fuel tank		Θ							Θ			
4	9	11.3	7.1	Adjustable seats		Θ										
5	9	10.3	6.5	Tire inflation system				Θ	O	O	O		▲		O	
6	9	9.9	6.3	GPS & Satellite Navigation system											Θ	
7	9	9.7	6.2	7.62-12.7 sw ivel gun mounts								Θ		Θ		
8	9	9.2	5.8	Modular structure design		Θ	O	O				O				
9	9	8.1	5.1	7.62 Remote w eapon station		O			O	O		O		Θ	Θ	
10	9	7.4	4.7	Unmanned variant	O	O	O					O		O	Θ	O
				Target or Limit Value	60 Km/h	2350mm/1600mm	75 deg, 65 deg, 18 deg	350mm	60%	40%	300mm, 300mm	soft skin-B6 (based of variant type)	500Km	7.62mm-12.7 (based of variant type)	500+ watt, 12V approx. 20 Ah	5 m
				Difficulty (0=Easy to Accomplish, 10=Extremely Difficult)	7	7	4	7	2	1	4	8	7	6	5	8
				Max Relationship Value in Column	9	9	3	9	3	3	3	9	9	9	9	3
				Weight / Importance	127.7	443.9	84.4	259.6	90.3	90.3	30.9	267.2	143.2	182.6	259.1	22.1
				Relative Weight	2.7	9.5	1.8	5.5	1.9	1.9	0.7	5.7	3.1	3.9	5.5	0.5

Row #	Column #	13	14	15	16	17	18	19	20	21	22	23	24	25	Competitive Analysis (0=Worst, 5=Best)				
	Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)	x	x	x	▼	x	x	x	x	x	x	▲	▼	▲					
	Demanded Quality	4 wheel Drive System	Differential Lock	Windshield	Vehicle Noise Level	suspension system	High strength lifting hocks	High strength detachable/foldable crew and bed roll bars	Sights	Communication System & GPS Antenna	Transmission	Max Payload	Curb Weight	Engine power	Our Company :2nd Gen. ATV II	Competitor 1 : 1st Gen. ATV I	Competitor 2: Polaris MRZR 2	Competitor 3: TOMCAR TM5	Competitor 4: JOHN DEERE M-Gator A2
1	Run-Flat Tires					Θ					O	Θ	Θ		4	2	5	5	2
2	Capability to be air deployed					Θ	Θ	Θ		O		Θ	Θ		4	1	5	4	3
3	Auxiliary fuel tank											Θ	Θ		5	0	2	2	2
4	Adjustable seats														5	0	1	1	1
5	Tire inflation system					O					O	O			5	0	1	1	1
6	GPS & Satellite Navigation system									Θ					4	0	4	4	2
7	7.62-12.7 sw ivel gun mounts							O					O		4	3	4	4	4
8	Modular structure design	O		Θ		O	O	Θ			O	Θ	Θ		5	2	3	3	2
9	7.62 Remote w eapon station					Θ		Θ	Θ	Θ		Θ	Θ	O	5	2	2	2	2
10	Unmanned variant		O		O	O		O	Θ	Θ	O	Θ	Θ	Θ	4	0	5	5	2
	Target or Limit Value	yes	yes	yes	75 dB	Independent double wishbone	yes	yes based of variant type)	yes based of variant type)	yes based of variant type)	CVT	500 kg	700 Kg	60 hp					
	Difficulty (0=Easy to Accomplish, 10=Extremely Difficult)	2	2	1	9	6	4	7	5	5	6	8	9	8					
	Max Relationship Value in Column	3	3	9	3	9	9	9	9	9	3	9	9	9					
	Weight / Importance	27.6	22.1	82.7	22.1	363.0	131.7	310.9	139.1	262.9	115.8	560.1	558.4	90.6					
	Relative Weight	0.6	0.5	1.8	0.5	7.7	2.8	6.6	3.0	5.6	2.5	11.9	11.9	1.9					

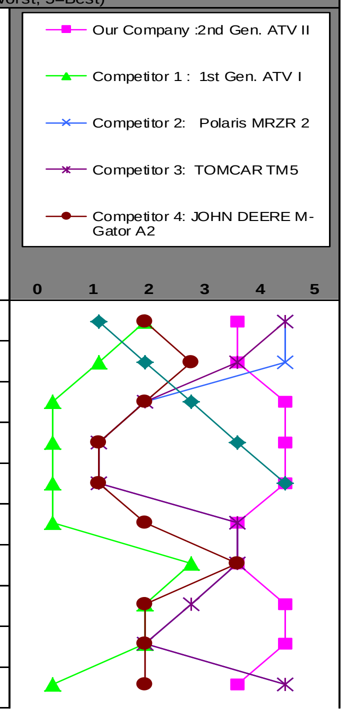


Figure 4-4 House of Quality, Kano based QFD

4.2.2.1.1 Final Target Values of the Dual Mode QFD

Based on the common functional requirements for both the QFD modes, it was possible to overlay the target values for the two modes. Subsequently, each value is compared with its adjacent value in the other QFD. Selection of criteria is then made for the value that can achieve the functional requirement in both modes. For example, the target value for top speed is 60 Km/h in the Kano based QFD, however, the top speed is 75 Km/h as found in the AHP based QFD. Consequently, the final target value out of the two modes QFD is 75 Km/h, as this value will inherently cover the 60 Km/h value.

By comparing all values, the final list of target values is developed as shown in Table 4-5.

Table 4-5 Final target values

Functional Requirement	Final target value
Top speed	75 Km/h
Wheel Base / Wheel Track	2350mm/1600mm
Clearance Angles (Approach, Departure, Ramp)	75 deg, 65 deg, 18 deg
Ground Clearance	350mm
Climbing ability	60%
Side Slop	40%
Ditch crossing, Fording	500mm, 500mm
Protection level	soft skin-B6 (based of variant type)
Cruising Range	500Km
Armament calibre	7.62mm-12.7 (based of variant type)

Functional Requirement	Final target value
High capacity electrical alternator, High capacity battery,	500+ watt, 12V approx. 20 Ah
Turning Radius	5 m
4 wheel Drive System	yes
Differential Lock	yes
Windshield	yes
Vehicle Noise Level	75 dB
suspension system	Independent double wishbone
High strength lifting hocks	yes
High strength detachable/foldable crew and bed roll bars	yes based of variant type)
Sights	yes (based of variant type)
Communication System & GPS Antenna	yes (based of variant type)
Transmission	CVT
Max Payload	500 kg
Curb Weight	700 Kg
Engine power	60 hp

4.3 Concept Development

The final results shown in this section will allow for an effective concept generation processes for the future concept engineering phase, which was not tackled in this research as mentioned earlier in the methodology section. The following functional modelling, and product architectural development sections will represent the results generated based on the systematic steps followed in the methodology section.

4.3.1 Functional Modelling

The functional modelling stage focused on how to achieve the final product functionality based on the customer wants. In that, the micro (basic) functions were developed to provide the necessary actions and methodologies to facilitate this goal.

Furthermore, the micro functions, were developed through the breakdown of the five levels within the hierarchical function structure discussed in section 3.4.1. For reference, the complete hierarchical function structure is shown in Appendix D

The final basic functions were listed based on their reference to the user requirements (main functions) category mentioned in sections 3.4.1.3.1 to 3.4.1.3.6.

4.3.1.1 Basic Functions - Mobility

Under this category, 28 basic functions were identified as shown in Table 4-6. By incorporating all the listed characteristics within the design process, this will eventually result in achieving the main function, which is mobility.

Table 4-6 Basic functions - mobility

No.	Basic function description	No.	Basic function description
1	Integrate imbedded hooks	15	Insulate battery & electronics
2	Use foldable structural components	16	Elevate exhaust outlet
3	Use lightweight structure	17	Elevate air intakes
4	Reduce sub-systems overall weight	18	Increase ramp angle
5	Improve maximum tractive effort	19	Increase approach angle
6	Improve engine tractive effort	20	Increase departure angle
7	Improve power-weight ratio	21	Use 4 wheels drive System
8	Reduce rolling resistance	22	Use differential Lock
9	Reduce gradient resistance	23	Setup for urban area
10	Reduce aerodynamic resistance	24	Setup for sand/desert
11	Use rack-and-pinion steering	25	Use tubular space frame
12	Increase size of disk brakes	26	Use high strength materials
13	Package heavy component	27	Fix lose components
14	Design low centre of gravity	28	Use high strength Joints

4.3.1.2 Basic functions - Lethality

The resulting basic functions within the lethality category were mainly based on allowing for future installation and integration of a light –medium weapon. The base MATV will not include a weapon as a standard feature – therefore, three basic functions were identified as shown in Table 4-7.

Table 4-7 Basic functions - lethality

No.	Basic function description
1	Allocate space/supporting structure for future hardware installation
2	Allocate power supply\interface for future hardware installation
3	Use MIL Spec. cables

4.3.1.3 Basic Functions - Survivability

The characteristics listed below in Table 4-8 allowed survivability to be maximised, including via integration of day and night vision functionality.

Table 4-8 Basic functions - survivability

No.	Basic function description
1	Allocate space/supporting structure for future hardware installation
2	Allocate power supply/interface for future hardware installation
3	Use standard military camouflage paint
4	Allocate add on armour-plates system or allocate provision for modular armour
5	Insulate engine compartment
6	Use non-pneumatic or auxiliary-supported tires

4.3.1.4 Basic Functions - Modularisation

Under this category, 4 basic functions were identified as shown in Table 4-9. The first two addressed the need to satisfy military and automotive standards for the electrical and structural design of the vehicle. The additional two functions addressed the need to share functionality among vehicle components and to use COTs components in order to facilitate the customisation process of the MATV base model.

Table 4-9 Basic functions - modularisation

No.	Basic function description
1	Meet MIL-STD requirements
2	Meet society of automotive engineers (SAE) requirements
3	Combine functions
4	Use standard components

4.3.1.5 Basic Functions - Support Battlefield Management System

The basic functions as shown in Table 4-10 were mainly focused on allowing future installation and integration of a GPS system, wireless network, and line of sight radio systems for the vehicle fleet – with the combat identification functionality, thermal panels, and blinking strobes included for ground-to-ground and air-to-ground target identification.

Table 4-10 Basic functions - support battlefield management system

No.	Basic function description
1	Allocate power supply/interface for future hardware installation
2	Allocate space/supporting structure for future hardware installation
3	Support wireless network connectivity

4	Support line of-sight radio transmission
5	Use thermal panels
6	Use IR blinking strobes

4.3.1.6 Basic functions - Account for general product development considerations

Under this category, as shown in Table 4-11, 37 basic functions were identified which support general product development considerations.

Table 4-11 Basic functions-account for general product development considerations

No.	Basic Function Description	No.	Basic Function Description
1	Include shovel	20	Pass design department quality test
2	Include axe	21	Include safety belts
3	Include sledge hammer	22	Include front/rear bumpers
4	Include pickaxe	23	Add side doors
5	Include receiver hitch	24	Add roll over bars
6	Multi-use towing eye	25	Add windshield
7	Include quick release locks	26	locate controls ergonomically
8	Include maintenance hatches	27	support ergonomically seating
9	Use recyclable materials	28	Follow ISO/TS 16949 standards
10	Reduce product materials	29	Follow human factors and ergonomics standards

11	Reuse/reduce packaging materials	30	Follow SAE interiors, cabins and cockpits standards
12	Reduce materials for production	31	Follow SAE safety standards
13	Design for inspection	32	Follow SAE noise, vibration and harshness standards
14	Reduce disassembly difficulty	33	Follow MIL interface standards
15	Use Mil-Spec numbering system	34	Follow MIL design criteria standards
16	Use fleet maintenance software	35	Follow Jordan's drivers and vehicles licensing requirements
17	Comply with military products disposal procedures	36	Use illustrative images and simplified maintenance\operational instructions
18	Pass test and evaluation verification test	37	Comply with military documentation procedures
19	Comply with Jordan Institution for Standards and Metrology (JISM)		

4.3.2 Product Architecture

In the ideal case, this stage can be fully achieved by generating a full and detailed interface matrix including all subsystems and components of the MATV. However, due to time limitation, and the inherent level of complexity, the outcome for this study will rely on results illustrated during the implementation work in section 3.4.2.1. In addition, the sample results for this study were illustrated in the basic 3D geometric images presented previously (Figure 3-32 plus Figure E-1 to Figure E-4 in Appendix E).

4.4 Summary and Overall Results

The overall results generated through the implementation of various methodologies applied in this study have shown improvements in the 2nd generation MATV when compared with the1st generation.

In order to demonstrate these improvements, a selected number of the main results (see Table 4-5 also Table 4-6 to Table 4-11) are compared with the current specifications of the first generation vehicle (see Figure F-1 in Appendix F). In this regard, a list of improvements and comparisons is given below:

- The resulting maximum/top speed for the 2nd generation MATV of 75km/h is a 25% improvement relative to that of the 1st generation (60km/h). This improvement is obtained via a number of enhancements made in the vehicle, including the reduction of the kerb weight, and increase in engine power.
- The proposed horse power for the 2nd generation MATV is 60hp, a 55% enhancement over the 1st generation MATV. Moreover, this enhancement is achieved by selecting turbo charged engine, which ensures compact size, and low weight – high power density engine.
- Wheel base for the 2nd generation MATV is 15% longer.
- Both the approach and departure angles are increased by 25% and 8% respectively resulting in better obstacle crossing.
- Ground clearance is increased by 20% for the 2nd generation MATV.

- Kerb Weight is reduced by 18% for the 2nd generation MATV. This is achieved by undertaking a more advanced structural analysis, thereby reducing the excess weight from areas that are lightly loaded. Moreover, lighter materials such as aluminium have been proposed for the space frame.
- Payload is increased by 50% for the 2nd generation MATV, this increase is achieved by incorporating higher strength springs and adjustable damping shock absorbers in the suspension system.
- Off-road range is increased by 36% for the 2nd generation. MATV; such an increase is mainly achieved by reducing the kerb weight of the vehicle and by selecting a more fuel effect engine.
- The 2nd generation MATV incorporates modular construction, which allows for a better and more consistent customisation process for future variants.
- The functional diagram for the 2nd generation. MATV (see Table 4-6 to Table 4-11) acts as a comprehensive checklist which confirms the above mentioned improvements in mobility, lethality, and survivability areas.

The above results have yet to be presented to the acting customers within this study in order for them to compare and verify the proposed improvements. This was not possible due to the time limitations, however such action is recommended before advancing in the product development process during the future studies

Finally, with the achieved results, there is still a need to refine and simplify the overall process. This can be achieved by reducing and combing implementation steps for Kano, AHP, and the integrated dual mode QFD.

5 CONCLUSIONS AND FUTURE WORK

5.1 Summary

This study originated to enhance the 1st generation MATV recently developed by KADDB. This vehicle is a light all-terrain vehicle capable of performing tactical and support missions in a relatively low operational complexity, at a low cost due to its simplicity in terms of construction, operation, and maintenance.

The design process undertaken to develop the first generation vehicle focused on the engineering and manufacturing aspects, with a little attention on the customer needs and system analysis. This led to vehicle that didn't fully meet the customer expectations, and resulted in partial satisfaction in areas such as performance and customisation.

The need for further improvement has necessitated the utilisation of new advanced and more efficient product development methodologies in order to achieve a well-balanced product in terms of functionality, performance and quality.

For that, the aim of this project was to propose and implement carefully selected methodologies starting from "Understand the Opportunity" and "Concept development" phases. While doing so, this work has managed to integrate both AHP and Kano methodologies into an innovative and novel approach named as "Integrated Dual Mode QFD" for the first phase. This resulted in utilising requirements which came at the top of both the analyses which allowed validation of user requirements and resulting technical specifications.

Thereafter, the study undertook functional modelling and Architectural design which led to a system that is well thought through and incorporates stakeholder views from KADDB and Jordanian Armed Forces (JAF).

This study is a first attempt to utilise the "Design Drivers" tool within the QFD analysis to select the most relevant and genuine FRs through a systematic graphical derivation process of the CRs.

As a final step, the preliminary interface analysis and product architecture of one sub-system was developed to demonstrate the results generated from the tools highlighted above and to lay the ground for future concept generation work.

Moreover, the study relied on a real case to ensure realistic assumptions and that a practical solution was achieved by implementing methodologies discussed in this thesis.

5.2 Conclusions

This study has successfully achieved the main aim of developing and integrating advanced product development methodologies in generating an architectural concept of a product under consideration - 2nd generation Militarised All-Terrain Vehicle (MATV).

The study has allowed the application of a comprehensive systematic approach in the early stages of product development process, resulting in clear and well defined input for the later stages including full concept generation and detailed design.

The application of design methodology to a real life problem has resulted in a realistic outcome which is verifiable as soon as 2^{nd} generation prototype is developed. A similar study concerning an integrated approach for the product development process has been reported by Cariaga et al. (2007)

The overall improvement to the vehicle included 55% increased power, 20% higher top speed, 18% reduced weight, 20% higher ground clearance, 25% improved approach angle, and 8% improved angle of departure. These improvements led to better agility, mobility, survivability, obstacle crossing and dash speed. The available space and loading capacities have been enhanced by increasing the wheel base and payload to 15% and 50% respectively.

Additionally, the modular architecture concept developed for the 2^{nd} generation MATV supports future variants with improved lethality, survivability, network-centric communication for better situational awareness and better compliance with local and international regulations and standards.

On the negative side, there are relatively an excessive number of implementation steps that need to be reduced or combined, such as in Kano and AHP.

In general, the overall process promises shorter system design and development time, while ensuring all aspects of customer voices have been taken into account to avoid costly integration issues later in the validation and verification stage.

5.3 Future Work

This study is a first step in establishing a more rigorous approach to concept design, through a systems approach where user needs are evaluated by two methods prior to establishing technical specifications, resulting in surer footsteps towards conceptual design. Nevertheless there are areas which, due to time constraints, this study has not managed to evaluate and therefore the following activities are proposed as part of further future work in the form of PhD study:

- Perform a full interaction analysis between all modules of the MATV, in order to develop a complete picture of the product architecture stage.
- Generate an advanced MATV concept based on the outcomes of this study in order to fully demonstrate the outcomes and advantages the proposed methodology developed here.
- Re-implement and refine the proposed methodology using a different case study, to enhance its compatibility with a wider range of products.

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APPENDICES

Appendix A Analytic Hierarchy Process (AHP)

A.1 Importance Evaluation Questionnaires Level I & Level II-A

New Product Development Questionnaire Level I

Name: ....

Job Title/Function: ....

Date questionnaire completed: ....

Temp. Title: 2nd Generation KADDB Light Tactical 4x4 All-Terrain Vehicle

Questionnaire Description: The questionnaire will highlight and prioritize the main enhanced characterises (at high level) of the 2nd generation KADDB Light Tactical 4x4 All-Terrain Vehicle.
As well-known, the current generation is exclusively designed to meet Jordan Armed Forces defence capabilities. It can be customized to be used as a tactical vehicle for agile forces with fast response actions by transporting in all terrain from 2 up to 4 soldiers of special operation, infantry or as logistic vehicle. The vehicle can also be deployed by land, sea, and air (C130 or Helicopter). (please refer to the back of the questioner for terms explanation)

No.	Question	Answers (circle one choice only)
1	How would you rank Mobility against Ergonomics?	Importance Level: Not ← → Extremely: 1 2 3 4 5 6 7 8 9 10
2	How would you rank Mobility against Survivability?	Importance Level: Not ← → Extremely: 1 2 3 4 5 6 7 8 9 10
3	How would you rank Mobility against Lethality?	Importance Level: Not ← → Extremely: 1 2 3 4 5 6 7 8 9 10
4	How would you rank Mobility against Deployability?	Importance Level: Not ← → Extremely: 1 2 3 4 5 6 7 8 9 10
5	How would you rank Mobility against Form?	Importance Level: Not ← → Extremely: 1 2 3 4 5 6 7 8 9 10

Figure A-1 Level I importance evaluation-complete questionnaire

No.	Question	Answers (circle one choice only)
6	How would you rank Mobility against Versatility?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10
No.	Question	Answers (circle one choice only)
7	How would you rank Mobility against Capacity?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10
No.	Question	Answers (circle one choice only)
8	How would you rank Mobility against Propulsion ?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10
No.	Question	Answers (circle one choice only)
9	How would you rank Mobility against Communications / Navigation ?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)
10	How would you rank Ergonomics against Survivability?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10
No.	Question	Answers (circle one choice only)
11	How would you rank Ergonomics against Lethality?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10
No.	Question	Answers (circle one choice only)
12	How would you rank Ergonomics against Deployability?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10
No.	Question	Answers (circle one choice only)
13	How would you rank Ergonomics against Form?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)
14	How would you rank Ergonomics against Versatility?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10
No.	Question	Answers (circle one choice only)
15	How would you rank Ergonomics against Capacity?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10
No.	Question	Answers (circle one choice only)
16	How would you rank Ergonomics against Propulsion ?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10
No.	Question	Answers (circle one choice only)
17	How would you rank Ergonomics against Communications / Navigation ?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10
No.	Question	Answers (circle one choice only)
18	How would you rank Survivability against Lethality?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10
No.	Question	Answers (circle one choice only)
19	How would you rank Survivability against Deployability?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10
No.	Question	Answers (circle one choice only)
20	How would you rank Survivability against Form?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10
No.	Question	Answers (circle one choice only)
21	How would you rank Survivability against Versatility?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)
22	How would you rank Survivability against Capacity?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)
23	How would you rank Survivability against Propulsion ?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)
24	How would you rank Survivability against Communications / Navigation ?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)
25	How would you rank Lethality against Deployability?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)
26	How would you rank Lethality against Form?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)
27	How would you rank Lethality against Versatility?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)
28	How would you rank Lethality against Capacity?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)
29	How would you rank Lethality against Propulsion ?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)
30	How would you rank Lethality against Communications / Navigation ?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)
31	How would you rank Deployability against Form?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)
32	How would you rank Deployability against Versatility?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)
33	How would you rank Deployability against Capacity?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)
34	How would you rank Deployability against Propulsion ?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)
35	How would you rank Deployability against Communications / Navigation ?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)
36	How would you rank Form against Versatility?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)
37	How would you rank Form against Capacity?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)
38	How would you rank Form against Propulsion ?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)
39	How would you rank Form against Communications / Navigation ?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)
40	How would you rank Versatility against Capacity?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)
41	How would you rank Versatility against Propulsion ?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)
42	How would you rank Versatility against Communications / Navigation ?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)
43	How would you rank Capacity against Propulsion ?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)
44	How would you rank Capacity against Communications / Navigation ?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)
45	How would you rank Propulsion against Communications / Navigation ?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10

Notes: (please add any other comments or suggestions)	

Term		Features covered
1	Mobility:	Max Speed, Slop climbing, Obstacles crossing, Natural Terrains Interaction, Manoeuvrability, Cruising range
2	Ergonomics	Visibility, Ride Comfort, Automation
3	Survivability	Protection from outside environment, Reduced Footprint, Ballistic Protection, Rollover Protection
4	Lethality	Lightweight weapons, Medium weight weapons, Precision munitions,
5	Deployability	Airlifted by helicopters, Parachute deployment, Transportability by C-130, Transportability by trailer
6	Form	Overall size limits, Weight limit, Clearance angles (departure, approach & ramp angles), Aesthetic Look
7	Versatility	Vehicle variants
8	Capacity	Crew number, payload, towing, Recoil force
9	Propulsion	Diesel, petrol, electrical , and/or hybrid power
10	Communications / Navigation	VHF, UHF, 2 way, audio and video data links, GPS
	Dedicated questioner will cover the above listed features in the next phases	
	Thank you	

New Product Development Questionnaire (Level II-A)	
Name:	
Job Title/Function:	
Date questionnaire completed:	
Temp. Title:	2nd Generation KADDB Light Tactical 4x4 All-Terrain Vehicle
Questionnaire Description:	The questionnaire will highlight and prioritize the main Level II-A characterises of the 2nd generation KADDB Light Tactical 4x4 All-Terrain Vehicle.

Mobility

No.	Question	Answers (circle one choice only) Importance Level Not ⟷ Extremely
1	How would you rank Max Speed against Slop climbing?	1 2 3 4 5 6 7 8 9 10
2	How would you rank Max Speed against Obstacles crossing?	1 2 3 4 5 6 7 8 9 10
3	How would you rank Max Speed against Natural Terrains Interaction?	1 2 3 4 5 6 7 8 9 10
4	How would you rank Max Speed against Manoeuvrability?	1 2 3 4 5 6 7 8 9 10
5	How would you rank Max Speed against Cruising range?	1 2 3 4 5 6 7 8 9 10
6	How would you rank Slop climbing against Obstacles crossing?	1 2 3 4 5 6 7 8 9 10

Figure A-2 Level II-A importance evaluation-complete questionnaire

No.	Question	Answers (circle one choice only)
7	How would you rank Slop climbing against Natural Terrains Interaction?	Importance Level Not ⟷ Extremely 1 2 3 4 5 6 7 8 9 10
No.	**Question**	**Answers (circle one choice only)**
8	How would you rank Slop climbing against Manoeuvrability?	Importance Level Not ⟷ Extremely 1 2 3 4 5 6 7 8 9 10
No.	**Question**	**Answers (circle one choice only)**
9	How would you rank Slop climbing against Cruising range?	Importance Level Not ⟷ Extremely 1 2 3 4 5 6 7 8 9 10
No.	**Question**	**Answers (circle one choice only)**
10	How would you rank Obstacles crossing against Natural Terrains Interaction?	Importance Level Not ⟷ Extremely 1 2 3 4 5 6 7 8 9 10
No.	**Question**	**Answers (circle one choice only)**
11	How would you rank Obstacles crossing against Manoeuvrability?	Importance Level Not ⟷ Extremely 1 2 3 4 5 6 7 8 9 10
No.	**Question**	**Answers (circle one choice only)**
12	How would you rank Obstacles crossing against Cruising range?	Importance Level Not ⟷ Extremely 1 2 3 4 5 6 7 8 9 10
No.	**Question**	**Answers (circle one choice only)**
13	How would you rank Natural Terrains Interaction against Manoeuvrability?	Importance Level Not ⟷ Extremely 1 2 3 4 5 6 7 8 9 10
No.	**Question**	**Answers (circle one choice only)**
14	How would you rank Natural Terrains Interaction against Cruising range?	Importance Level Not ⟷ Extremely 1 2 3 4 5 6 7 8 9 10
No.	**Question**	**Answers (circle one choice only)**
15	How would you rank Manoeuvrability against Cruising range?	Importance Level Not ⟷ Extremely 1 2 3 4 5 6 7 8 9 10

Ergonomics		
No.	**Question**	**Answers (circle one choice only)**
16	How would you rank Visibility against Ride Comfort?	**Importance Level** **Not** ⟷ **Extremely** **1 2 3 4 5 6 7 8 9 10**
No.	**Question**	**Answers (circle one choice only)**
17	How would you rank Visibility against Automation?	**Importance Level** **Not** ⟷ **Extremely** **1 2 3 4 5 6 7 8 9 10**
No.	**Question**	**Answers (circle one choice only)**
18	How would you rank Ride Comfort against Automation?	**Importance Level** **Not** ⟷ **Extremely** **1 2 3 4 5 6 7 8 9 10**

Survivability		
No.	**Question**	**Answers (circle one choice only)**
19	How would you rank Protection from outside environment against Reduced Footprint?	**Importance Level** **Not** ⟷ **Extremely** **1 2 3 4 5 6 7 8 9 10**
No.	**Question**	**Answers (circle one choice only)**
20	How would you rank Protection from outside environment against Ballistic Protection?	**Importance Level** **Not** ⟷ **Extremely** **1 2 3 4 5 6 7 8 9 10**
No.	**Question**	**Answers (circle one choice only)**
21	How would you rank Protection from outside environment against Rollover Protection?	**Importance Level** **Not** ⟷ **Extremely** **1 2 3 4 5 6 7 8 9 10**
No.	**Question**	**Answers (circle one choice only)**
22	How would you rank Reduced Footprint against Ballistic Protection?	**Importance Level** **Not** ⟷ **Extremely** **1 2 3 4 5 6 7 8 9 10**
No.	**Question**	**Answers (circle one choice only)**
23	How would you rank Reduced Footprint against Rollover Protection?	**Importance Level** **Not** ⟷ **Extremely** **1 2 3 4 5 6 7 8 9 10**

No.	Question	Answers (circle one choice only)
24	How would you rank Ballistic Protection against Rollover Protection?	Importance Level: Not ←→ Extremely; 1 2 3 4 5 6 7 8 9 10

Lethality

No.	Question	Answers (circle one choice only)
25	How would you Light-Medium weight weapons against Medium-Heavy weight weapons?	Importance Level: Not ←→ Extremely; 1 2 3 4 5 6 7 8 9 10
26	How would you rank Light-Medium weight weapons against Precision munitions?	Importance Level: Not ←→ Extremely; 1 2 3 4 5 6 7 8 9 10
27	How would you rank Medium-Heavy weight weapons against Precision munitions?	Importance Level: Not ←→ Extremely; 1 2 3 4 5 6 7 8 9 10

Deployability

No.	Question	Answers (circle one choice only)
28	How would you rank Parachute deployment against Transportability by C-130?	Importance Level: Not ←→ Extremely; 1 2 3 4 5 6 7 8 9 10
29	How would you rank Parachute deployment against Transportability by trailer?	Importance Level: Not ←→ Extremely; 1 2 3 4 5 6 7 8 9 10
30	How would you rank Parachute deployment against Compatibility with Airlift by helicopters?	Importance Level: Not ←→ Extremely; 1 2 3 4 5 6 7 8 9 10
31	How would you rank Transportability by C-130 against Transportability by trailer?	Importance Level: Not ←→ Extremely; 1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)
32	How would you rank Transportability by C-130 against Compatibility with Airlift by helicopters?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)
33	How would you rank Transportability by trailer against Compatibility with Airlift by helicopters?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10

Form

No.	Question	Answers (circle one choice only)
34	How would you rank Overall size limits against Weight limit?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)
35	How would you rank Overall size limits against Clearance angles?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)
36	How would you rank Overall size limits against Aesthetic Look?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)
37	How would you rank Weight limit against Clearance angles?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)
38	How would you rank Weight limit against Aesthetic Look?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)
39	How would you rank Clearance angles against Aesthetic Look?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10

Versatility		
No.	**Question**	**Answers (circle one choice only)** Importance Level
40	How would you rank Reconnaissance vehicle against Fighting vehicle?	Not ← → Extremely 1 2 3 4 5 6 7 8 9 10
No.	**Question**	**Answers (circle one choice only)** Importance Level
41	How would you rank Reconnaissance vehicle against Troup carrier vehicle?	Not ← → Extremely 1 2 3 4 5 6 7 8 9 10
No.	**Question**	**Answers (circle one choice only)** Importance Level
42	How would you rank Reconnaissance vehicle against Unmanned vehicle?	Not ← → Extremely 1 2 3 4 5 6 7 8 9 10
No.	**Question**	**Answers (circle one choice only)** Importance Level
43	How would you rank Reconnaissance vehicle against Logistics vehicle?	Not ← → Extremely 1 2 3 4 5 6 7 8 9 10
No.	**Question**	**Answers (circle one choice only)** Importance Level
44	How would you rank Reconnaissance vehicle against command an control vehicle?	Not ← → Extremely 1 2 3 4 5 6 7 8 9 10
No.	**Question**	**Answers (circle one choice only)** Importance Level
45	How would you rank Fighting vehicle vehicle against Troup carrier vehicle?	Not ← → Extremely 1 2 3 4 5 6 7 8 9 10
No.	**Question**	**Answers (circle one choice only)** Importance Level
46	How would you rank Fighting vehicle vehicle against Unmanned vehicle?	Not ← → Extremely 1 2 3 4 5 6 7 8 9 10
No.	**Question**	**Answers (circle one choice only)** Importance Level
47	How would you rank Fighting vehicle vehicle against Logistics vehicle?	Not ← → Extremely 1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)									
		Importance Level									
		Not									Extremely
48	How would you rank Fighting vehicle vehicle against command an control vehicle?	1	2	3	4	5	6	7	8	9	10

No.	Question	Answers (circle one choice only)									
		Importance Level									
		Not									Extremely
49	How would you rank Troup carrier vehicle against Unmanned vehicle?	1	2	3	4	5	6	7	8	9	10

No.	Question	Answers (circle one choice only)									
		Importance Level									
		Not									Extremely
50	How would you rank Troup carrier vehicle vehicle against Logistics vehicle?	1	2	3	4	5	6	7	8	9	10

No.	Question	Answers (circle one choice only)									
		Importance Level									
		Not									Extremely
51	How would you rank Troup carrier vehicle against command an control vehicle?	1	2	3	4	5	6	7	8	9	10

No.	Question	Answers (circle one choice only)									
		Importance Level									
		Not									Extremely
52	How would you rank Unmanned vehicle vehicle against Logistics vehicle?	1	2	3	4	5	6	7	8	9	10

No.	Question	Answers (circle one choice only)									
		Importance Level									
		Not									Extremely
53	How would you rank Unmanned vehicle against command an control vehicle?	1	2	3	4	5	6	7	8	9	10

No.	Question	Answers (circle one choice only)									
		Importance Level									
		Not									Extremely
54	How would you rank Logistics vehicle against command an control vehicle?	1	2	3	4	5	6	7	8	9	10

Capacity

No.	Question	Answers (circle one choice only)									
		Importance Level									
		Not									Extremely
55	How would you rank Number of crew against Payload?	1	2	3	4	5	6	7	8	9	10

No.	Question	Answers (circle one choice only)
56	How would you rank Number of crew against Towing load?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10
No.	Question	Answers (circle one choice only)
57	How would you rank Number of crew against Recoil shock absorption?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10
No.	Question	Answers (circle one choice only)
58	How would you rank Payload against Towing load?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10
No.	Question	Answers (circle one choice only)
59	How would you rank Payload against Recoil shock absorption?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10
No.	Question	Answers (circle one choice only)
60	How would you rank Towing load Recoil shock absorption?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10
	Propulsion	
No.	Question	Answers (circle one choice only)
61	How would you rank Diesel Engine against Petrol Engine?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10
No.	Question	Answers (circle one choice only)
62	How would you rank Diesel Engine against Electrical Motor?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10
No.	Question	Answers (circle one choice only)
63	How would you rank Diesel Engine against Hybrid Engine?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)
64	How would you rank Petrol Engine against Electrical Motor?	Importance Level Not ← → Extremely 1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)
65	How would you rank Petrol Engine against Hybrid Engine?	Importance Level Not ← → Extremely 1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)
66	How would you rank Electrical Motor against Hybrid Engine?	Importance Level Not ← → Extremely 1 2 3 4 5 6 7 8 9 10

Communications / Navigation

No.	Question	Answers (circle one choice only)
67	How would you rank VHF/ UHF Radios option against 2 way, audio and video data links option?	Importance Level Not ← → Extremely 1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)
68	How would you rank VHF/ UHF Radios option against GPS option?	Importance Level Not ← → Extremely 1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)
69	How would you rank 2 way, audio and video data links option against GPS option?	Importance Level Not ← → Extremely 1 2 3 4 5 6 7 8 9 10

Notes: (please add any other comments or suggestions)

Thank you

A.2 Importance Evaluation Answer Tables

Table A-1 Importance evaluation answer table-Level I

Questionnaire		Avg. Result	Customer 1	Customer 2	Customer 3	Customer 4	Customer 5	Customer 6	Customer 7	Customer 8	Customer 9	Customer 10	Customer 11	Customer 12	Customer 13	Customer 14	Customer 15	Customer 16	Customer 17	Customer 18	Customer 19	Customer 20
No.	Question																					
1	Mobility vs Ergonomics	6.95	7	8	5	10	9	7	6	7	7	6	5	7	5	8	6	6	7	8	7	8
2	Mobility vs Survivability	5.95	5	7	5	4	5	6	6	8	9	5	7	5	6	6	5	5	8	6	5	6
3	Mobility vs Lethality	6.5	5	5	10	5	6	8	7	6	9	7	8	4	5	8	5	5	8	6	6	7
4	Mobility vs Deployability	6.5	7	5	6	5	5	6	7	9	7	7	5	8	7	5	6	5	9	8	8	5
5	Mobility vs Form	6.5	6	8	5	9	4	6	8	6	8	8	10	2	7	9	4	6	8	6	5	5
6	Mobility vs Versatility	6.4	7	3	6	7	5	5	4	8	7	7	5	7	7	6	7	6	7	8	8	8
7	Mobility vs Capacity	6.5	6	7	5	6	5	7	8	7	6	7	8	5	5	8	6	6	8	6	7	7
8	Mobility vs Propulsion	6.3	7	4	5	7	8	5	4	7	7	5	10	5	6	9	4	6	7	6	7	7
9	Mobility vs Communications / Navigation	6.3	6	4	10	7	5	6	6	6	9	6	10	4	4	5	5	5	4	9	7	8
10	Ergonomics vs Survivability	4.6	4	4	5	2	4	4	7	7	8	4	5	2	5	4	7	4	6	3	5	2
11	Ergonomics vs Lethality	4.55	4	4	7	3	5	6	4	6	7	4	4	2	4	4	6	4	6	3	4	4
12	Ergonomics vs Deployability	5.05	5	5	8	5	4	4	4	8	4	4	9	1	7	4	4	4	7	6	3	5
13	Ergonomics vs Form	5.3	4	5	5	5	4	6	4	6	8	4	10	5	7	7	3	3	8	4	3	5
14	Ergonomics vs Versatility	5.35	5	5	5	3	5	4	3	7	6	6	10	5	4	7	5	5	3	6	6	7
15	Ergonomics vs Capacity	5.5	5	7	8	3	4	4	6	7	5	6	6	10	5	3	4	5	8	4	5	5
16	Ergonomics vs Propulsion	4.8	5	4	5	3	5	5	4	7	4	4	6	9	6	3	3	3	3	3	6	8
17	Ergonomics vs Communications / Navigation	5.3	4	6	9	3	3	3	4	6	8	4	10	9	6	3	3	3	3	5	6	8
18	Survivability vs Lethality	5.85	5	5	9	8	5	6	3	6	3	5	8	5	4	6	6	6	8	5	6	8
19	Survivability vs Deployability	6.45	7	7	5	7	9	5	7	8	3	6	10	8	6	5	5	5	7	8	6	5
20	Survivability vs Form	7.05	6	8	5	9	8	6	7	7	4	7	10	9	6	9	7	7	7	5	6	8
21	Survivability vs Versatility	6.7	7	6	5	8	9	5	4	7	3	7	10	8	7	7	6	6	7	8	6	8
22	Survivability vs Capacity	6.25	6	6	7	5	8	6	4	8	2	7	8	6	5	5	7	7	8	5	7	8
23	Survivability vs Propulsion	5.75	7	6	5	7	8	5	4	7	2	5	7	3	7	5	6	6	5	5	7	8
24	Survivability vs Communications / Navigation	6.35	7	4	8	6	8	7	6	6	5	7	9	5	5	5	5	5	6	7	8	8
25	Lethality vs Deployability	5.95	7	7	7	6	5	3	4	7	3	6	10	5	5	3	5	5	6	8	8	9
26	Lethality vs Form	6.2	6	6	4	6	6	3	4	7	5	6	9	8	7	8	6	5	7	5	8	8
27	Lethality vs Versatility	6.1	7	6	5	6	5	3	4	7	4	7	8	7	7	5	7	6	6	8	6	8
28	Lethality vs Capacity	5.5	6	7	5	5	6	4	4	7	3	7	6	5	4	3	6	7	7	5	5	8
29	Lethality vs Propulsion	5.6	7	5	4	6	9	3	6	7	2	7	3	5	6	5	6	6	5	5	7	8
30	Lethality vs Communications / Navigation	5.55	7	4	5	6	6	4	4	6	5	7	8	5	6	3	5	5	6	7	7	5
31	Deployability vs Form	6.35	5	9	3	6	6	7	6	8	8	7	8	8	8	5	5	5	8	3	6	6
32	Deployability vs Versatility	6.1	5	7	3	5	5	6	4	8	8	7	9	7	6	7	7	7	7	5	4	5
33	Deployability vs Capacity	5.8	5	6	3	4	8	6	6	8	5	7	7	5	8	5	6	6	7	3	4	7
34	Deployability vs Propulsion	5.45	5	5	3	5	8	5	7	7	5	6	4	5	6	8	6	6	5	3	5	5
35	Deployability vs Communications / Navigation	5.45	4	4	9	5	7	6	4	7	9	5	9	3	5	3	5	5	3	5	4	7
36	Form vs Versatility	5.05	6	7	5	4	4	4	4	7	3	5	4	3	7	3	6	5	7	8	4	5
37	Form vs Capacity	4.8	6	8	5	4	4	4	4	8	2	5	1	2	6	3	6	5	7	6	4	6
38	Form vs Propulsion	4.7	6	7	8	4	5	4	3	7	3	4	1	2	6	4	5	5	3	6	6	5
39	Form vs Communications / Navigation	5.15	5	6	8	3	5	5	4	7	5	3	6	1	6	3	5	6	3	7	7	8
40	Versatility vs Capacity	5	4	7	5	3	6	6	8	7	2	5	3	4	5	3	7	7	7	3	5	3
41	Versatility vs Propulsion	4.85	4	7	5	3	7	6	8	7	2	4	2	2	7	7	5	5	5	3	6	2
42	Versatility vs Communications / Navigation	4.65	4	4	8	3	6	6	6	6	5	4	4	3	5	3	4	4	4	5	6	3
43	Capacity vs Propulsion	5.5	6	6	5	7	7	5	4	7	5	5	5	4	6	7	4	4	4	8	6	5
44	Capacity vs Communications / Navigation	5.9	5	5	7	7	6	5	6	6	8	5	9	3	6	5	5	5	5	8	6	6
45	Propulsion vs Communications / Navigation	5.65	5	4	7	3	4	6	6	6	8	6	9	5	5	3	6	6	3	7	5	9

Table A-2 Importance evaluation answer table-Level II-A

	Questionnaire		Avg. Result	Customer 1	Customer 2	Customer 3	Customer 4	Customer 5	Customer 6	Customer 7	Customer 8	Customer 9	Customer 10	Customer 11	Customer 12	Customer 13	Customer 14	Customer 15	Customer 16	Customer 17	Customer 18	Customer 19	Customer 20
	No.	Question																					
Mobility	1	Max Speed vs Slop climbing	5.3	6	8	5	3	4	6	8	8	6	5	3	4	7	3	4	4	8	2	4	8
	2	Max Speed vs Obstacles crossing	5.15	6	5	5	4	4	6	4	9	6	4	7	3	7	3	4	4	8	2	4	8
	3	Max Speed vs Natural Terrains Interaction	5.5	6	8	6	4	4	4	4	9	5	4	5	3	5	5	6	6	8	5	5	8
	4	Max Speed vs Manoeuvrability	5.15	5	6	8	4	3	3	4	8	4	4	4	5	7	3	4	4	9	5	6	7
	5	Max Speed vs Cruising range	5.3	6	8	5	4	3	5	7	8	5	4	1	5	6	5	5	5	6	5	5	8
	6	Slop climbing vs Obstacles crossing	5.9	5	6	4	6	5	5	4	8	5	6	10	5	8	5	6	5	8	6	4	7
	7	Slop climbing vs Natural Terrains Interaction	6.3	5	7	4	6	5	4	7	8	5	5	10	5	8	7	7	7	8	8	5	5
	8	Slop climbing vs Manoeuvrability	5.65	4	5	4	6	5	6	4	7	5	5	10	3	8	5	5	5	7	8	4	7
	9	Slop climbing vs Cruising range	6.35	5	4	4	6	7	6	4	8	8	5	10	8	7	8	6	6	5	8	5	7
	10	Obstacles crossing vs Natural Terrains Interaction	6.05	5	8	5	5	4	5	6	8	5	5	5	5	8	7	7	7	7	7	4	8
	11	Obstacles crossing vs Manoeuvrability	5.75	4	5	5	5	5	7	7	8	7	5	3	6	8	6	5	5	6	7	4	7
	12	Obstacles crossing vs Cruising range	5.9	6	4	5	5	4	7	7	8	8	5	1	8	7	7	6	6	7	6	5	6
	13	Natural Terrains Interaction vs Manoeuvrability	5.3	5	7	5	5	5	7	6	8	7	5	2	4	7	4	5	5	6	4	4	5
	14	Natural Terrains Interaction vs Cruising range	5.6	7	7	5	6	4	6	6	7	6	4	1	5	6	6	6	6	7	5	5	7
	15	Manoeuvrability vs Cruising range	6.4	7	5	8	6	8	4	7	8	6	6	4	7	7	8	7	6	5	6	5	8
Ergonomics	16	Visibility vs Ride Comfort	5.65	7	7	5	6	8	7	3	7	5	5	1	5	5	5	7	7	9	4	4	6
	17	Visibility vs Automation	6.35	7	5	5	6	7	7	7	7	7	7	10	7	6	5	6	6	5	6	6	5
	18	Ride Comfort vs Automation	6	6	5	5	4	6	7	7	8	7	7	10	4	5	8	4	4	5	7	6	5
Survivability	19	Protection from outside environment vs Reduced Footprint	5.55	6	6	3	3	7	4	3	7	8	5	6	5	4	3	5	5	9	9	8	5
	20	Protection from outside environment vs Ballistic Protection	5.1	3	5	2	2	8	4	7	5	8	4	6	3	3	8	4	4	9	5	7	5
	21	Protection from outside environment vs Rollover Protection	4.45	4	5	8	4	7	4	4	5	5	4	1	5	4	4	3	4	7	4	6	1
	22	Reduced Footprint vs Ballistic Protection	5.5	3	5	8	3	4	6	8	6	8	7	7	4	5	8	3	4	9	3	3	6
	23	Reduced Footprint vs Rollover Protection	4.1	3	5	6	5	4	4	4	6	5	5	1	5	4	3	4	4	4	3	4	3
	24	Ballistic Protectiont vs Rollover Protection	4.7	5	5	2	8	7	4	3	7	3	6	1	5	4	3	4	5	5	5	7	5
Lethality	25	Light-Medium weight weapons vs Medium-Heavy weight weapons	6.8	4	7	7	8	7	7	8	7	9	4	10	8	5	8	6	4	8	8	5	6
	26	Light-Medium weight weapons vs Precision munitions	5.6	4	7	7	6	5	7	8	7	5	4	5	5	6	3	5	4	7	7	4	6
	27	Medium-Heavy weight weapons vs Precision munitions	4.5	4	8	2	4	4	3	7	7	1	4	2	2	7	3	6	5	6	6	4	5
Deployability	28	Parachute deployment vs Transportability by C-130	5.9	3	8	5	7	6	4	9	8	8	5	5	5	9	9	5	6	7	5	3	1
	29	Parachute deployment vs Transportability by trailer	5.25	3	4	5	7	4	4	6	9	8	6	3	9	5	9	6	5	4	3	4	1
	30	Parachute deployment vs Compatibility with Airlift by helicopters	5.05	3	7	3	5	4	5	4	8	5	5	3	5	7	5	5	5	8	5	4	5
	31	Transportability by C-130 vs Transportability by trailer	5.55	7	7	5	7	6	6	8	8	9	5	5	2	6	5	4	4	3	3	6	5
	32	Transportability by C-130 vs Compatibility with Airlift by helicopters	5.15	7	6	5	3	6	6	5	8	3	5	6	5	7	3	4	4	3	5	5	7
	33	Transportability by trailer vs Compatibility with Airlift by helicopters	5.3	6	5	5	3	4	6	4	8	4	5	9	2	8	5	5	6	3	8	4	6
Form	34	Overall size limits vs Weight limit	5.65	5	7	5	4	5	5	3	9	5	5	5	5	7	8	5	5	8	5	4	8
	35	Overall size limits vs Clearance angles	5.3	5	7	4	5	3	6	7	9	3	5	5	5	8	3	6	3	8	4	5	5
	36	Overall size limits vs Aesthetic Look	7.25	7	7	8	7	3	7	8	9	8	7	10	7	7	8	5	6	7	9	6	9
	37	Weight limit vs Clearance angles	5.65	5	7	5	6	4	6	8	8	5	5	5	3	6	3	4	5	7	8	5	8
	38	Weight limit vs Aesthetic Look	6.4	7	5	5	7	3	6	8	8	8	7	10	5	6	3	6	7	4	9	5	9
	39	Clearance angles vs Aesthetic Look	6.9	7	6	8	7	3	6	8	8	9	7	10	9	7	8	4	6	3	8	5	9
Versatility	40	Reconnaissance vs Fighting vehicle	6.35	4	5	9	8	7	7	9	6	8	5	5	8	9	8	4	4	7	5	4	5
	41	Reconnaissance vs Troup carrier	6.35	5	5	5	8	7	7	9	6	9	7	5	8	8	6	6	5	6	5	5	5
	42	Reconnaissance vs Unmanned	6.1	6	7	5	6	5	7	7	7	9	5	3	5	6	5	5	6	8	9	6	5
	43	Reconnaissance vs Logistics	5.6	5	4	5	6	8	6	4	7	8	5	2	8	7	8	3	5	6	5	5	5
	44	Reconnaissance vs Command and Control	5.7	5	4	9	6	8	6	4	7	9	5	5	5	5	4	6	4	6	5	6	5
	45	Fighting vehicle vs Troup carrier	5.6	5	5	5	3	3	5	7	8	7	7	5	9	6	5	5	5	7	5	5	5
	46	Fighting vehicle vs Unmanned	6.1	7	6	5	4	3	6	6	8	8	5	3	9	8	3	7	6	7	9	7	5
	47	Fighting vehicle vs Logistics	5.45	6	5	5	4	3	4	4	8	8	5	4	8	6	7	6	5	5	5	6	5
	48	Fighting vehicle vs Command and Control	5.2	6	5	4	4	3	5	4	7	8	6	5	5	7	2	4	6	7	5	6	5
	49	Troup carriere vs Unmanned	5	6	4	5	5	2	7	6	7	6	3	4	5	5	3	5	6	1	9	6	5
	50	Troup carrier vs Logistics	5.2	6	6	5	5	2	6	3	8	6	3	4	7	5	3	6	5	8	5	6	5
	51	Troup carrier vs Command and Control	4.55	6	4	4	5	2	6	3	8	6	3	2	5	4	2	5	5	6	5	5	5
	52	Unmanned vs Logistics	4.75	5	5	5	5	4	4	3	8	5	5	6	3	4	8	4	4	6	2	4	5
	53	Unmanned vs Command and Control	4.5	5	4	3	5	3	4	3	8	5	7	5	3	3	5	5	4	7	2	4	5
	54	Logistics vs Command and Control	5.7	5	4	8	5	8	6	7	8	5	7	8	5	5	3	6	5	4	5	5	5
Capacity	55	Number of crew members vs Payload	5.15	5	7	5	5	3	5	3	8	8	5	1	5	5	5	4	4	9	5	4	7
	56	Number of crew members vs Towing load	6.5	6	6	9	5	3	7	8	9	7	6	5	7	6	8	6	4	5	8	7	8
	57	Number of crew members vs Recoil shock absorption	5.9	4	7	9	4	3	7	7	8	6	4	1	8	9	8	5	3	7	5	5	8
	58	Payload vs Towing load	7.3	7	6	9	5	7	8	9	8	6	7	10	10	7	7	6	5	5	8	7	9
	59	Payload vs Recoil shock absorption	6.3	4	6	9	4	4	8	8	8	6	5	6	5	8	8	5	5	8	5	5	9
	60	Towing load vs Recoil shock absorption	4.35	4	4	3	4	3	4	4	8	6	5	5	3	7	2	4	4	3	5	4	5
Propulsion	61	Diesel Engine vs Petrol Engine	6.9	7	7	10	6	7	6	7	9	9	8	5	8	4	5	3	6	7	9	6	9
	62	Diesel Engine vs Electrical Motor Engine	7.6	7	5	10	8	5	7	8	9	9	8	5	10	7	9	4	7	8	10	6	10
	63	Diesel Engine vs Hybrid System	7.05	5	5	10	8	3	7	9	9	9	8	4	10	3	9	3	5	8	10	6	10
	64	Petrol Engine vs Electrical Motor Engine	6.5	6	5	1	7	5	7	7	8	9	4	6	10	8	6	4	6	8	9	6	8
	65	Petrol Engine vs Hybrid System	5.9	5	5	1	7	3	7	7	8	7	5	3	10	6	5	2	5	8	8	6	10
	66	Electrical Motor Engine vs Hybrid System	4.4	4	6	1	4	5	3	4	6	1	5	3	3	2	5	5	3	6	6	6	10
Communications / Navigation	67	VHF/ UHF Radios vs 2 way, audio and video data links	5.05	6	6	5	3	3	8	4	6	5	7	5	5	3	5	5	4	5	5	5	6
	68	VHF/ UHF Radios vs GPS	5	5	5	2	7	5	8	7	6	5	7	3	5	3	3	4	5	5	5	5	5
	69	2 way, audio and video data links vs GPS	5.25	4	4	2	7	5	8	7	7	5	6	2	5	5	5	7	6	5	5	5	5

A.3 Eigenvector - general MATLAB code

```
A=  [1.0    a12     a13     a14     a1n;
    1/a12   1.0     a23     a24     a2n;
    1/a13   1/a23   1.0     a34     a3n;
    1/a14   1/a24   1/a34   1.0     a4n;
    1/a1n   1/a2n   1/a3n   1/a4n   1.0];
[priorvec,evec]=eig(A);
avec=diag(evec);
norm=sum(priorvec);
[x,zi]=max(avec)
for ii=1:n
    for jj=1:n
        priorvec(jj,11)=priorvec(jj,ii)/norm(ii);
    end
end
x=norm(1);
vvec=priorvec(1:n,zi)/x
```

A.4 Global Importance

Table A-3 Lethality, global importance

Level II-A, Lethality							
Lethality Requrements		R4-1 Light-Medium weight weapons	R4-2 Medium-Heavy weight weapons	R4-3 Precision munitions	**Eigenvector (relative importance)**	**Lethality (relative importance)**	**Global importance**
R4-1	Light-Medium weight weapons	1	2.1250	1.2727	**0.4484**	**0.1086**	**0.04869624**
R4-2	Medium-Heavy weight weapons	0.4706	1	0.8182	**0.2341**		**0.02542326**
R4-3	Precision munitions	0.7857	1.2222	1	**0.3175**		**0.0344805**

Table A-4 Deployability, global importance

Level II-A, Deployability								
Deployability Requrements		R5-1 Parachute deployment	R5-2 Transportability by C-130	R5-3 Transportability by trailer	R5-4 Compatibility with Airlift by helicopters	**Eigenvector (relative importance)**	**Deployability (relative importance)**	**Global importance**
R5-1	Parachute deployment	1	1.4390	1.1053	1.0202	**0.282**	**0.0976**	**0.0275232**
R5-2	Transportability by C-130	0.6949	1	1.2472	1.0619	**0.2448**		**0.02389248**
R5-3	Transportability by trailer	0.9048	0.8018	1	1.1277	**0.2368**		**0.02311168**
R5-4	Compatibility with Airlift by helicopters	0.9802	0.9417	0.8868	1	**0.2364**		**0.02307264**

TableA-5 Form, global importance

Level II-A, Form								
Form Requrements		R6-1	R6-2	R6-3	R6-4	Eigenvector (relative importance)	Form (relative importance)	Global importance
		Overall size limits	Weight limit	Clearance angles	Aesthetic Look			
R6-1	Overall size limits	1	1.2989	1.1277	2.6364	0.3306	0.0731	0.02416686
R6-2	Weight limit	0.7699	1	1.2989	1.7778	0.2744		0.02005864
R6-3	Clearance angles	0.8868	0.7699	1	2.2258	0.2634		0.01925454
R6-4	Aesthetic Look	0.3793	0.5625	0.4493	1	0.1316		0.00961996

TableA-6 Versatility, global importance

Level II-A, Versatility										
Versatility Requrements		R7-1	R7-2	R7-3	R7-4	R7-5	R7-6	Eigenvector (relative importance)	Versatility (relative importance)	Global importance
		Reconnaissance	Fighting vehicle	Troup carrier	Unmanned	Logistics	Command and Control			
R7-1	Reconnaissance	1	1.7397	1.7397	1.5641	1.2727	1.3256	0.2322	0.0746	0.01732212
R7-2	Fighting vehicle	0.5748	1	1.2727	1.5641	1.1978	1.0833	0.1753		0.01307738
R7-3	Troup carrier	0.5748	0.7857	1	1.0000	1.0833	0.8349	0.1408		0.01050368
R7-4	Unmanned	0.6393	0.6393	1.0000	1	0.9048	0.8182	0.1338		0.00998148
R7-5	Logistics	0.7857	0.8349	0.9231	1.1053	1	1.3256	0.1613		0.01203298
R7-6	Command and Control	0.7544	0.9231	1.1978	1.2222	0.7544	1	0.1567		0.01168982

Table A-7 Capacity, global importance

Level II-A, Capacity								
Capacity Requrements		R8-1	R8-2	R8-3	R8-4	Eigenvector (relative importance)	Capacity (relative importance)	Global importance
		Number of crew members	Payload	Towing load	Recoil shock absorption			
R8-1	Number of crew members	1	1.0619	1.8571	1.4390	0.3078	0.0856	0.02634768
R8-2	Payload	0.9417	1	2.7037	1.7027	0.3425		0.029318
R8-3	Towing load	0.5385	0.3699	1	0.7699	0.1483		0.01269448
R8-4	Recoil shock absorption	0.6949	0.5873	1.2989	1	0.2014		0.01723984

TableA-8 Propulsion, global importance

Level II-A, Propulsion								
Propulsion Requrements		R9-1 Diesel Engine	R9-2 Petrol Engine	R9-3 Electrical Motor Engine	R9-4 Hybrid System	Eigenvector (relative importance)	Propulsion (relative importance)	Global importance
R9-1	Diesel Engine	1	2.2258	3.1667	2.3898	**0.4549**	**0.0876**	**0.03984924**
R9-2	Petrol Engine	0.4493	1	1.8571	1.4390	**0.235**		**0.020586**
R9-3	Electrical Motor Engine	0.3158	0.5385	1	0.7857	**0.1354**		**0.01186104**
R9-4	Hybrid System	0.4184	0.6949	1.2727	1	**0.1747**		**0.01530372**

Table A-9 Comm. /Nav., global importance

Level II-A, Communications / Navigation							
Communications / Navigation Requrements		R10-1 VHF/ UHF Radios	R10-2 2 way, audio and video data links	R10-3 GPS	Eigenvector (relative importance)	Communications / Navigation (relative importance)	Global importance
R10-1	VHF/ UHF Radios	1	1.0202	1.0000	**0.3355**	**0.0777**	**0.02606835**
R10-2	2 way, audio and video data links	0.9802	1	1.1053	**0.3422**		**0.02658894**
R10-3	GPS	1.0000	0.9048	1	**0.3223**		**0.02504271**

Appendix B Kano Model

B.1 Appendix Kano Questionnaire

New Product Development Questionnaire (Level III)

Name: ______________________

Job Title/Function: ______________________

Date questionnaire completed: ______________________

No.	Question	Answers (select with a X one choice only)
1A	If the vehicle has tire inflation system	____ 1. I like it ____ 2. I expect it ____ 3. I'm neutral ____ 4. I can tolerate it ____ 5. I dislike it
No.	**Question**	**Answers (select with a X one choice only)**
1B	If the vehicle doesn't have tire inflation system	____ 1. I like it ____ 2. I expect it ____ 3. I'm neutral ____ 4. I can tolerate it ____ 5. I dislike it
No.	**Question**	**Answers (select with a X one choice only)**
2A	If the vehicle has adjustable seats	____ 1. I like it ____ 2. I expect it ____ 3. I'm neutral ____ 4. I can tolerate it ____ 5. I dislike it
No.	**Question**	**Answers (select with a X one choice only)**
2B	If the vehicle doesn't have adjustable seats	____ 1. I like it ____ 2. I expect it ____ 3. I'm neutral ____ 4. I can tolerate it ____ 5. I dislike it
No.	**Question**	**Answers (select with a X one choice only)**
3A	If the vehicle has enclosed crew compartment	____ 1. I like it ____ 2. I expect it ____ 3. I'm neutral ____ 4. I can tolerate it ____ 5. I dislike it
No.	**Question**	**Answers (select with a X one choice only)**
3B	If the vehicle doesn't have enclosed crew compartment	____ 1. I like it ____ 2. I expect it ____ 3. I'm neutral ____ 4. I can tolerate it ____ 5. I dislike it

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Figure B-1 Kano questionnaire- complete

No.	Question	Answers (select with a X one choice only)
4A	If the vehicle has multi engine variants	______ 1. I like it ______ 2. I expect it ______ 3. I'm neutral ______ 4. I can tolerate it ______ 5. I dislike it
No.	Question	Answers (select with a X one choice only)
4B	If the vehicle doesn't have multi engine variants	______ 1. I like it ______ 2. I expect it ______ 3. I'm neutral ______ 4. I can tolerate it ______ 5. I dislike it
No.	Question	Answers (select with a X one choice only)
5A	If the vehicle has radio communication system	______ 1. I like it ______ 2. I expect it ______ 3. I'm neutral ______ 4. I can tolerate it ______ 5. I dislike it
No.	Question	Answers (select with a X one choice only)
5B	If the vehicle doesn't have radio communication system	______ 1. I like it ______ 2. I expect it ______ 3. I'm neutral ______ 4. I can tolerate it ______ 5. I dislike it
No.	Question	Answers (select with a X one choice only)
6A	If the vehicle has Run-Flat Tires	______ 1. I like it ______ 2. I expect it ______ 3. I'm neutral ______ 4. I can tolerate it ______ 5. I dislike it
No.	Question	Answers (select with a X one choice only)
6B	If the vehicle doesn't have Run-Flat Tires	______ 1. I like it ______ 2. I expect it ______ 3. I'm neutral ______ 4. I can tolerate it ______ 5. I dislike it
No.	Question	Answers (select with a X one choice only)
7A	If the vehicle has GPS & Satellite Navigation system	______ 1. I like it ______ 2. I expect it ______ 3. I'm neutral ______ 4. I can tolerate it ______ 5. I dislike it
No.	Question	Answers (select with a X one choice only)
7B	If the vehicle doesn't have GPS & Satellite Navigation system	______ 1. I like it ______ 2. I expect it ______ 3. I'm neutral ______ 4. I can tolerate it ______ 5. I dislike it

No.	Question	Answers (select with a X one choice only)
8A	If the vehicle has armour protection	____ 1. I like it ____ 2. I expect it ____ 3. I'm neutral ____ 4. I can tolerate it ____ 5. I dislike it
No.	Question	Answers (select with a X one choice only)
8B	If the vehicle doesn't have armour protection	____ 1. I like it ____ 2. I expect it ____ 3. I'm neutral ____ 4. I can tolerate it ____ 5. I dislike it
No.	Question	Answers (select with a X one choice only)
9A	If the vehicle has cooking vessel	____ 1. I like it ____ 2. I expect it ____ 3. I'm neutral ____ 4. I can tolerate it ____ 5. I dislike it
No.	Question	Answers (select with a X one choice only)
9B	If the vehicle doesn't have cooking vessel	____ 1. I like it ____ 2. I expect it ____ 3. I'm neutral ____ 4. I can tolerate it ____ 5. I dislike it
No.	Question	Answers (select with a X one choice only)
10A	If the vehicle has 7.62-12.7 swivel gun mounts	____ 1. I like it ____ 2. I expect it ____ 3. I'm neutral ____ 4. I can tolerate it ____ 5. I dislike it
No.	Question	Answers (select with a X one choice only)
10B	If the vehicle doesn't have 7.62-12.7 swivel gun mounts	____ 1. I like it ____ 2. I expect it ____ 3. I'm neutral ____ 4. I can tolerate it ____ 5. I dislike it
No.	Question	Answers (select with a X one choice only)
11A	If the vehicle has 7.62 Remote weapon station	____ 1. I like it ____ 2. I expect it ____ 3. I'm neutral ____ 4. I can tolerate it ____ 5. I dislike it
No.	Question	Answers (select with a X one choice only)
11B	If the vehicle doesn't have 7.62 remote weapon station	____ 1. I like it ____ 2. I expect it ____ 3. I'm neutral ____ 4. I can tolerate it ____ 5. I dislike it

No.	Question	Answers (select with a X one choice only)
12A	If the vehicle has unmanned variant	____ 1. I like it ____ 2. I expect it ____ 3. I'm neutral ____ 4. I can tolerate it ____ 5. I dislike it
No.	**Question**	**Answers (select with a X one choice only)**
12B	If the vehicle doesn't have unmanned variant	____ 1. I like it ____ 2. I expect it ____ 3. I'm neutral ____ 4. I can tolerate it ____ 5. I dislike it
No.	**Question**	**Answers (select with a X one choice only)**
13A	If the vehicle has auxiliary fuel tank	____ 1. I like it ____ 2. I expect it ____ 3. I'm neutral ____ 4. I can tolerate it ____ 5. I dislike it
No.	**Question**	**Answers (select with a X one choice only)**
13B	If the vehicle doesn't have auxiliary fuel tank	____ 1. I like it ____ 2. I expect it ____ 3. I'm neutral ____ 4. I can tolerate it ____ 5. I dislike it
No.	**Question**	**Answers (select with a X one choice only)**
14A	If the vehicle has petrol engine	____ 1. I like it ____ 2. I expect it ____ 3. I'm neutral ____ 4. I can tolerate it ____ 5. I dislike it
No.	**Question**	**Answers (select with a X one choice only)**
14B	If the vehicle doesn't have petrol engine	____ 1. I like it ____ 2. I expect it ____ 3. I'm neutral ____ 4. I can tolerate it ____ 5. I dislike it
No.	**Question**	**Answers (select with a X one choice only)**
15A	If the vehicle has electrical motor engine	____ 1. I like it ____ 2. I expect it ____ 3. I'm neutral ____ 4. I can tolerate it ____ 5. I dislike it
No.	**Question**	**Answers (select with a X one choice only)**
15B	If the vehicle doesn't have electrical motor engine	____ 1. I like it ____ 2. I expect it ____ 3. I'm neutral ____ 4. I can tolerate it ____ 5. I dislike it

No.	Question	Answers (select with a X one choice only)
16A	If the vehicle has the capability to be air deployed	______ 1. I like it ______ 2. I expect it ______ 3. I'm neutral ______ 4. I can tolerate it ______ 5. I dislike it
No.	Question	Answers (select with a X one choice only)
16B	If the vehicle doesn't have the capability to be air deployed	______ 1. I like it ______ 2. I expect it ______ 3. I'm neutral ______ 4. I can tolerate it ______ 5. I dislike it
No.	Question	Answers (select with a X one choice only)
17A	If the vehicle has the capability to be fitted with tracks	______ 1. I like it ______ 2. I expect it ______ 3. I'm neutral ______ 4. I can tolerate it ______ 5. I dislike it
No.	Question	Answers (select with a X one choice only)
17B	If the vehicle doesn't have the capability to be fitted with tracks	______ 1. I like it ______ 2. I expect it ______ 3. I'm neutral ______ 4. I can tolerate it ______ 5. I dislike it
No.	Question	Answers (select with a X one choice only)
18A	If the vehicle has modular structure design	______ 1. I like it ______ 2. I expect it ______ 3. I'm neutral ______ 4. I can tolerate it ______ 5. I dislike it
No.	Question	Answers (select with a X one choice only)
18B	If the vehicle doesn't have modular structure design	______ 1. I like it ______ 2. I expect it ______ 3. I'm neutral ______ 4. I can tolerate it ______ 5. I dislike it

No.	Question	Answers (circle one choice only)
1C	How would you rank the tire inflation system feature?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)
2C	How would you rank the adjustable seats feature?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)
3C	How would you rank the enclosed crew compartment feature?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)
4C	How would you rank the multi engine variants option?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)
5C	How would you rank the radio communication system feature?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)
6C	How would you rank the Run-Flat Tires option?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)
7C	How would you rank the GPS & Satellite Navigation system features?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)
8C	How would you rank the armour protection feature?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)
9C	How would you rank the cooking vessel feature?	Importance Level Not ←→ Extremely 1 2 3 4 5 6 7 8 9 10

No.	Question	Answers (circle one choice only)									
		Importance Level									
		Not									Extremely
10C	How would you rank the 7.62-12.7 swivel gun mounts feature?	1	2	3	4	5	6	7	8	9	10

No.	Question	Answers (circle one choice only)									
		Importance Level									
		Not									Extremely
11C	How would you rank the 7.62 Remote weapon station feature?	1	2	3	4	5	6	7	8	9	10

No.	Question	Answers (circle one choice only)									
		Importance Level									
		Not									Extremely
12C	How would you rank the unmanned variant feature?	1	2	3	4	5	6	7	8	9	10

No.	Question	Answers (circle one choice only)									
		Importance Level									
		Not									Extremely
13C	How would you rank the auxiliary fuel tank feature?	1	2	3	4	5	6	7	8	9	10

No.	Question	Answers (circle one choice only)									
		Importance Level									
		Not									Extremely
14C	How would you rank the petrol engine feature?	1	2	3	4	5	6	7	8	9	10

No.	Question	Answers (circle one choice only)									
		Importance Level									
		Not									Extremely
15C	How would you rank the electrical motor engine feature?	1	2	3	4	5	6	7	8	9	10

No.	Question	Answers (circle one choice only)									
		Importance Level									
		Not									Extremely
16C	How would you rank the capability to be air deployed feature?	1	2	3	4	5	6	7	8	9	10

No.	Question	Answers (circle one choice only)									
		Importance Level									
		Not									Extremely
17C	How would you rank the capability to be fitted with tracks feature?	1	2	3	4	5	6	7	8	9	10

No.	Question	Answers (circle one choice only)									
		Importance Level									
		Not									Extremely
18C	How would you rank the modular structure design feature?	1	2	3	4	5	6	7	8	9	10

Notes: (please add any other comments or suggestions)

Thank you

B.2 KANO Answer Table

Table B-1 Kano answer table-complete

Questionnaire			Customer 1	Customer 2	Customer 3	Customer 4	Customer 5	Customer 6	Customer 7	Customer 8	Customer 9	Customer 10	Customer 11	Customer 12	Customer 13	Customer 14	Customer 15	Customer 16	Customer 17	Customer 18	Customer 19	Customer 20
		Name:																				
		Company Name:																				
		Job Title/Function:																				
		Date questionnaire completed:																				
		Interviewers name (if applicable):																				

No.	Question	Answers (select with a X one choice only)	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20
1A	If the vehicle has tire inflation system	1. I like it				X				X		X					X		X	X	X	
		2. I expect it		X			X							X	X			X				
		3. I'm neutral	X		X			X					X			X						X
		4. I can tolerate it									X											
		5. I dislike it							X													
1B	If the vehicle doesn't have tire inflation system	1. I like it																				
		2. I expect it			X						X											
		3. I'm neutral	X				X	X	X			X	X		X	X	X			X		X
		4. I can tolerate it												X				X			X	
		5. I dislike it		X		X				X									X			
1C	How would you rank the tire inflation system feature?	Importance Level: Not ← → Extremely; 1 2 3 4 5 6 7 8 9 10	5	9	1	8	8	3	3	6	7	5	5	8	8	8	6	8	9	5	9	9
		Evaluation	I	M	I	O	I	I	R	O	I	A	I	I	I	I	A	I	O	A	A	I
			5	9	1	8	8	3	3	6	7	5	5	8	8	8	6	8	9	5	9	9

No.	Question	Answers (select with a X one choice only)	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20
2A	If the vehicle has adjustable seats	1. I like it	X		X					X		X			X					X	X	
		2. I expect it		X			X	X			X		X	X		X	X	X	X			X
		3. I'm neutral				X			X													
		4. I can tolerate it																				
		5. I dislike it																				
2B	If the vehicle doesn't have adjustable seats	1. I like it																				
		2. I expect it			X																	
		3. I'm neutral				X	X	X	X											X		
		4. I can tolerate it								X	X	X			X	X		X	X		X	
		5. I dislike it	X	X									X	X			X					X
2C	How would you rank the adjustable seats feature?	Importance Level: Not ← → Extremely; 1 2 3 4 5 6 7 8 9 10	9	7	1	5	7	6	4	9	8	8	10	10	9	5	9	7	8	3	7	10
		Evaluation	O	M	A	I	I	I	I	A	I	A	M	M	A	I	M	I	I	A	A	M
			9	7	1	5	7	6	4	9	8	8	10	10	9	5	9	7	8	3	7	10

No.	Question	Answers (select with a X one choice only)	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20
3A	If the vehicle has enclosed crew compartment	1. I like it	X								X	X		X		X					X	
		2. I expect it				X	X	X		X							X	X		X		
		3. I'm neutral											X		X				X			X
		4. I can tolerate it		X																		
		5. I dislike it			X				X													
3B	If the vehicle doesn't have enclosed crew compartment	1. I like it			X				X													
		2. I expect it																				
		3. I'm neutral		X			X	X					X	X	X	X	X		X			X
		4. I can tolerate it				X				X		X						X		X	X	
		5. I dislike it	X								X											
3C	How would you rank the enclosed crew compartment feature?	Importance Level: Not ← → Extremely; 1 2 3 4 5 6 7 8 9 10	8	5	3	4	7	3	3	6	8	5	5	9	8	3	7	6	6	7	4	5
		Evaluation	O	I	R	I	I	I	R	I	O	A	I	A	I	A	I	I	I	I	A	I
			8	5	3	4	7	3	3	6	8	5	5	9	8	3	7	6	6	7	4	5

No.	Question	Answers (select with a X one choice only)	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20
4A	If the vehicle has multi engine variants	1. I like it	X		X					X		X	X					X				X
		2. I expect it					X	X	X						X						X	
		3. I'm neutral				X					X					X	X		X	X		
		4. I can tolerate it		X																		
		5. I dislike it												X								
4B	If the vehicle doesn't have multi engine variants	1. I like it					X							X								
		2. I expect it																				
		3. I'm neutral		X	X	X		X	X		X		X		X	X	X	X	X	X	X	X
		4. I can tolerate it								X		X										
		5. I dislike it	X																			
4C	How would you rank the multi engine variants option?	Importance Level: Not ← → Extremely; 1 2 3 4 5 6 7 8 9 10	8	5	6	4	6	7	7	10	6	7	8	5	7	5	2	6	5	3	5	5
		Evaluation	O	I	A	I	R	I	I	A	I	A	A	R	I	I	I	A	I	I	I	A
			8	5	6	4	6	7	7	10	6	7	8	5	7	5	2	6	5	3	5	5

No.	Question	Answers (select with a X one choice only)	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers
5A	If the vehicle has radio communication system	1. I like it							X				X		X		X												X				X								
		2. I expect it	X								X							A			X				X		X								X				X		X
		3. I'm neutral			X		X							A					X				X								X			A			X				
		4. I can tolerate it														A														A											
		5. I dislike it								O																															
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers
5B	If the vehicle doesn't have radio communication system	1. I like it									X	R																													
		2. I expect it															X											I												I	
		3. I'm neutral		I			X						X						X				X				X				X		X			I	X		X		
		4. I can tolerate it	X		X										X							M				M			X						X						
		5. I dislike it							X												X				X																X
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers
5C	How would you rank the radio communication system feature?	Importance Level Not Extremely 1 2 3 4 5 6 7 8 9 10	7		5	I	2	I	6		7		7		5		7		3	I	8		5	I	10		6		9		3	I	6		6		4	I	5		9
				7		5		2		6		7		7		5		7		3		8		5		10		6		9		3		6		6		4		5	

No.	Question	Answers (select with a X one choice only)	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers
6A	If the vehicle has Run-Flat Tires	1. I like it							X				X		X		X				X		X		X		X				X				X						
		2. I expect it	X		X						X								X										X				X				X				
		3. I'm neutral												A										A		A		A				A							X		X
		4. I can tolerate it																A																		A					
		5. I dislike it					X			O						O						O																			
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers
6B	If the vehicle doesn't have Run-Flat Tires	1. I like it									X	R																													
		2. I expect it					X																											I							
		3. I'm neutral		I									X										X		X		X				X		X					I	X		X
		4. I can tolerate it	X			M											X			M										M					X		X				
		5. I dislike it			X				X						X				X		X								X												
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers
6C	How would you rank the Run-Flat Tires option?	Importance Level Not Extremely 1 2 3 4 5 6 7 8 9 10	9		9		1		9		8		8		8		6		7		7		8		10		5		10		7		8		8		8		4	I	8
								R																																	
				9		9		1		9		8		8		8		6		7		7		8		10		5		10		7		8		8		8		4	

No.	Question	Answers (select with a X one choice only)	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers
7A	If the vehicle has GPS & Satellite Navigation system	1. I like it											X				X				X		X		X		X				X		X						X		
		2. I expect it	X						X		X			A				A	X										X						X					A	X
		3. I'm neutral			X		X																	A		A		A				A		A			X				
		4. I can tolerate it																																							
		5. I dislike it													X							O																			
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers
7B	If the vehicle doesn't have GPS & Satellite Navigation system	1. I like it													X																										
		2. I expect it										I	X				X																						X		
		3. I'm neutral		I			X			I	X									I			X		X		X			I	X		X			I	X				
		4. I can tolerate it	X		X				X										X										X						X						
		5. I dislike it																			X																				X
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers
7C	How would you rank the GPS & Satellite Navigation system features?	Importance Level Not Extremely 1 2 3 4 5 6 7 8 9 10	7		5	I	3	I	7		8		6		8		8		4		8		8		5		8		8		2		6		6		4	I	4		10
														R																											
				7		5		3		7		8		6		8		8		4		8		8		5		8		8		2		6		6		4		4	

No.	Question	Answers (select with a X one choice only)	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers
8A	If the vehicle has armour protection	1. I like it	X								X	Q							X		X		X		X				X		X						X				
		2. I expect it			X				X				X														X						X						X		
		3. I'm neutral													X		X					A		A		A						A			X			A			X
		4. I can tolerate it		A																A										A											
		5. I dislike it					X																																		
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers
8B	If the vehicle doesn't have armour protection	1. I like it									X																														
		2. I expect it					X							I			X																							I	
		3. I'm neutral				I				I			X		X						X		X		X			I			X				X		X		X		X
		4. I can tolerate it	X		X				X										X								X		X					M							
		5. I dislike it																															X								
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers
8C	How would you rank the armour protection feature?	Importance Level Not Extremely 1 2 3 4 5 6 7 8 9 10	8		6		1		5		7		5		5	I	6	I	5		5		7		8		7		6		5		7		5	I	6		5		5
								R																																	
				8		6		1		5		7		5		5		6		5		5		7		8		7		6		5		7		5		6		5	

No.	Question	Answers (select with a X one choice only)	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers
9A	If the vehicle has cooking vessel	1. I like it																					X				X				X		X								
		2. I expect it																			X																				
		3. I'm neutral	X		X						X													A				A	X			A		A	X		X		X		
		4. I can tolerate it							X				X		X		X																								
		5. I dislike it					X												X						X																X
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers
9B	If the vehicle doesn't have cooking vessel	1. I like it																	X																						X
		2. I expect it					X																																		
		3. I'm neutral	X								X		X		X							I	X		X		X		X		X		X		X		X		X		
		4. I can tolerate it			X				X								X				X																				
		5. I dislike it																																							
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers
9C	How would you rank the cooking vessel feature?	Importance Level Not Extremely 1 2 3 4 5 6 7 8 9 10	5	I	4	I	1		4		6	I	3		4		8		2		4		6		1		8		3	I	8		5		5	I	2	I	4	I	1
								R		I				I		I		I		R						R															
				5		4		1		4		6		3		4		8		2		4		6		1		8		3		8		5		5		2		4	

No.	Question	Answers (select with a X one choice only)	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation
10A	If the vehicle has 7.62-12.7 swivel gun mounts	1. I like it					X				X	
		2. I expect it	X		X							
		3. I'm neutral						A	X			A
		4. I can tolerate it										
		5. I dislike it										
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers	
10B	If the vehicle doesn't have 7.62-12.7 swivel gun mounts	1. I like it										
		2. I expect it				I						
		3. I'm neutral		I	X		X		X		X	
		4. I can tolerate it	X									
		5. I dislike it										
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers	
10C	How would you rank the 7.62-12.7 swivel gun mounts feature?	Importance Level Not Extremely 1 2 3 4 5 6 7 8 9 10	8		6		6		5	I	6	
				8		6		6		5		6

No.	Question	Answers (select with a X one choice only)	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation
10A	If the vehicle has 7.62-12.7 swivel gun mounts	1. I like it					X					
		2. I expect it	X		X				X		X	
		3. I'm neutral										
		4. I can tolerate it						A				
		5. I dislike it										
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers	
10B	If the vehicle doesn't have 7.62-12.7 swivel gun mounts	1. I like it										
		2. I expect it				I						
		3. I'm neutral		I	X					I		
		4. I can tolerate it	X				X		X			M
		5. I dislike it									X	
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers	
10C	How would you rank the 7.62-12.7 swivel gun mounts feature?	Importance Level Not Extremely 1 2 3 4 5 6 7 8 9 10	5		6		6		5		8	
				5		6		6		5		8

No.	Question	Answers (select with a X one choice only)	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation
10A	If the vehicle has 7.62-12.7 swivel gun mounts	1. I like it			X				X		X	
		2. I expect it				A						
		3. I'm neutral	X				X					
		4. I can tolerate it								A		
		5. I dislike it										O
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers	
10B	If the vehicle doesn't have 7.62-12.7 swivel gun mounts	1. I like it										
		2. I expect it			X							
		3. I'm neutral	X				X					
		4. I can tolerate it							X			
		5. I dislike it									X	
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers	
10C	How would you rank the 7.62-12.7 swivel gun mounts feature?	Importance Level Not Extremely 1 2 3 4 5 6 7 8 9 10	5	I	4		5	I	7		6	
				5		4		5		7		6

No.	Question	Answers (select with a X one choice only)	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers
10A	If the vehicle has 7.62-12.7 swivel gun mounts	1. I like it					X		X		X		
		2. I expect it	X		X								
		3. I'm neutral						A					
		4. I can tolerate it								A		A	
		5. I dislike it											
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers		Answers
10B	If the vehicle doesn't have 7.62-12.7 swivel gun mounts	1. I like it											
		2. I expect it											
		3. I'm neutral				I	X						
		4. I can tolerate it		M	X				X		X		
		5. I dislike it	X										
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers		Answers
10C	How would you rank the 7.62-12.7 swivel gun mounts feature?	Importance Level Not Extremely 1 2 3 4 5 6 7 8 9 10	6		7		6		8		8		
				6		7		6		8		8	

No.	Question	Answers (select with a X one choice only)	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation
11A	If the vehicle has 7.62 Remote weapon station	1. I like it			X				X		X	
		2. I expect it										
		3. I'm neutral	X			A						A
		4. I can tolerate it								A		
		5. I dislike it					X					
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers	
11B	If the vehicle doesn't have 7.62 remote weapon station	1. I like it										
		2. I expect it					X					
		3. I'm neutral	X		X						X	
		4. I can tolerate it							X			
		5. I dislike it										
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers	
11C	How would you rank the 7.62 Remote weapon station feature?	Importance Level Not Extremely 1 2 3 4 5 6 7 8 9 10	5	I	6		1		5		7	
								R				
				5		6		1		5		7

No.	Question	Answers (select with a X one choice only)	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation
11A	If the vehicle has 7.62 Remote weapon station	1. I like it			X							
		2. I expect it									X	
		3. I'm neutral	X				X		X			
		4. I can tolerate it										
		5. I dislike it				O						
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers	
11B	If the vehicle doesn't have 7.62 remote weapon station	1. I like it										
		2. I expect it										
		3. I'm neutral	X				X		X			I
		4. I can tolerate it									X	
		5. I dislike it			X							
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers	
11C	How would you rank the 7.62 Remote weapon station feature?	Importance Level Not Extremely 1 2 3 4 5 6 7 8 9 10	5	I	8		6	I	3	I	7	
				5		8		6		3		7

No.	Question	Answers (select with a X one choice only)	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation
11A	If the vehicle has 7.62 Remote weapon station	1. I like it			X				X		X	
		2. I expect it										
		3. I'm neutral	X				X			A		A
		4. I can tolerate it				A						
		5. I dislike it										
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers	
11B	If the vehicle doesn't have 7.62 remote weapon station	1. I like it										
		2. I expect it										
		3. I'm neutral	X				X		X		X	
		4. I can tolerate it			X							
		5. I dislike it										
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers	
11C	How would you rank the 7.62 Remote weapon station feature?	Importance Level Not Extremely 1 2 3 4 5 6 7 8 9 10	5	I	4		5	I	6		6	
				5		4		5		6		6

No.	Question	Answers (select with a X one choice only)	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers
11A	If the vehicle has 7.62 Remote weapon station	1. I like it	X				X		X				
		2. I expect it											
		3. I'm neutral		A	X			A			X		
		4. I can tolerate it								A			
		5. I dislike it											
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers		Answers
11B	If the vehicle doesn't have 7.62 remote weapon station	1. I like it											
		2. I expect it											
		3. I'm neutral	X		X		X				X		
		4. I can tolerate it							X				
		5. I dislike it											
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers		Answers
11C	How would you rank the 7.62 Remote weapon station feature?	Importance Level Not Extremely 1 2 3 4 5 6 7 8 9 10	5		5	I	6		6		1	I	
				5		5		6		6		1	

No.	Question	Answers (select with a X one choice only)	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation
12A	If the vehicle has unmanned variant	1. I like it			X						X	
		2. I expect it										
		3. I'm neutral	X									A
		4. I can tolerate it				A						
		5. I dislike it					X		X			
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers	
12B	If the vehicle doesn't have unmanned variant	1. I like it							X			
		2. I expect it					X					
		3. I'm neutral	X								X	
		4. I can tolerate it			X							
		5. I dislike it										
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers	
12C	How would you rank the unmanned variant feature?	Importance Level Not Extremely 1 2 3 4 5 6 7 8 9 10	5	I	5		3		4		7	
								R		R		
				5		5		3		4		7

No.	Question	Answers (select with a X one choice only)	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation
12A	If the vehicle has unmanned variant	1. I like it									X	
		2. I expect it										
		3. I'm neutral	X		X							
		4. I can tolerate it					X					A
		5. I dislike it							X			
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers	
12B	If the vehicle doesn't have unmanned variant	1. I like it							X			
		2. I expect it										
		3. I'm neutral			X							
		4. I can tolerate it	X				X				X	
		5. I dislike it										
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers	
12C	How would you rank the unmanned variant feature?	Importance Level Not Extremely 1 2 3 4 5 6 7 8 9 10	4	I	5	I	6		1		6	
								I		R		
				4		5		6		1		6

No.	Question	Answers (select with a X one choice only)	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation
12A	If the vehicle has unmanned variant	1. I like it	X		X				X		X	
		2. I expect it										
		3. I'm neutral				A	X			A		A
		4. I can tolerate it		A								
		5. I dislike it										
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers	
12B	If the vehicle doesn't have unmanned variant	1. I like it										
		2. I expect it										
		3. I'm neutral			X		X		X		X	
		4. I can tolerate it	X									
		5. I dislike it										
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers	
12C	How would you rank the unmanned variant feature?	Importance Level Not Extremely 1 2 3 4 5 6 7 8 9 10	9		5		3	I	3		8	
				9		5		3		3		8

No.	Question	Answers (select with a X one choice only)	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers
12A	If the vehicle has unmanned variant	1. I like it	X										
		2. I expect it							X				
		3. I'm neutral		A	X						X		
		4. I can tolerate it											
		5. I dislike it					X						
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers		Answers
12B	If the vehicle doesn't have unmanned variant	1. I like it											
		2. I expect it					X			I			
		3. I'm neutral	X		X				X		X		
		4. I can tolerate it											
		5. I dislike it											
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers		Answers
12C	How would you rank the unmanned variant feature?	Importance Level Not Extremely 1 2 3 4 5 6 7 8 9 10	4		5	I	1		4		5	I	
								R					
				4		5		1		4		5	

No.	Question	Answers (select with a X one choice only)	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation
13A	If the vehicle has auxiliary fuel tank	1. I like it	X				X				X	
		2. I expect it			X			A				
		3. I'm neutral										A
		4. I can tolerate it		A					X			
		5. I dislike it										
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers	
13B	If the vehicle doesn't have auxiliary fuel tank	1. I like it										
		2. I expect it				I	X					
		3. I'm neutral			X						X	
		4. I can tolerate it	X						X			
		5. I dislike it										
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers	
13C	How would you rank the auxiliary fuel tank feature?	Importance Level Not Extremely 1 2 3 4 5 6 7 8 9 10	8		6		7		7		7	
										I		
				8		6		7		7		7

No.	Question	Answers (select with a X one choice only)	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation
13A	If the vehicle has auxiliary fuel tank	1. I like it					X		X			
		2. I expect it	X		X						X	
		3. I'm neutral										
		4. I can tolerate it								A		
		5. I dislike it						O				
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers	
13B	If the vehicle doesn't have auxiliary fuel tank	1. I like it										
		2. I expect it				I						
		3. I'm neutral		I	X							I
		4. I can tolerate it	X						X		X	
		5. I dislike it					X					
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers	
13C	How would you rank the auxiliary fuel tank feature?	Importance Level Not Extremely 1 2 3 4 5 6 7 8 9 10	6		4		9		8		8	
				6		4		9		8		8

No.	Question	Answers (select with a X one choice only)	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation
13A	If the vehicle has auxiliary fuel tank	1. I like it			X		X		X			
		2. I expect it	X			A					X	
		3. I'm neutral										
		4. I can tolerate it						A		A		
		5. I dislike it										
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers	
13B	If the vehicle doesn't have auxiliary fuel tank	1. I like it										
		2. I expect it			X							I
		3. I'm neutral									X	
		4. I can tolerate it		M			X		X			
		5. I dislike it	X									
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers	
13C	How would you rank the auxiliary fuel tank feature?	Importance Level Not Extremely 1 2 3 4 5 6 7 8 9 10	10		7		7		7		5	
				10		7		7		7		5

No.	Question	Answers (select with a X one choice only)	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers
13A	If the vehicle has auxiliary fuel tank	1. I like it	X				X		X		X		
		2. I expect it			X			A					
		3. I'm neutral		A								A	
		4. I can tolerate it								A			
		5. I dislike it											
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers		Answers
13B	If the vehicle doesn't have auxiliary fuel tank	1. I like it											
		2. I expect it					X						
		3. I'm neutral	X			I					X		
		4. I can tolerate it			X				X				
		5. I dislike it											
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers		Answers
13C	How would you rank the auxiliary fuel tank feature?	Importance Level Not Extremely 1 2 3 4 5 6 7 8 9 10	5		8		4		6		8		
				5		8		4		6		8	

No.	Question	Answers (select with a X one choice only)	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation
14A	If the vehicle has petrol engine	1. I like it									X	Q
		2. I expect it			X							
		3. I'm neutral							X			
		4. I can tolerate it										
		5. I dislike it	X				X					
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers	
14B	If the vehicle doesn't have petrol engine	1. I like it	X				X				X	
		2. I expect it				I						
		3. I'm neutral			X				X			
		4. I can tolerate it										
		5. I dislike it										
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers	
14C	How would you rank the petrol engine feature?	Importance Level Not Extremely 1 2 3 4 5 6 7 8 9 10	3		6		5		5	I	6	
				R				R				
				3		6		5		5		6

No.	Question	Answers (select with a X one choice only)	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation
14A	If the vehicle has petrol engine	1. I like it					X					
		2. I expect it										
		3. I'm neutral			X			A			X	
		4. I can tolerate it	X									
		5. I dislike it							X			
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers	
14B	If the vehicle doesn't have petrol engine	1. I like it										
		2. I expect it	X									
		3. I'm neutral			X		X				X	
		4. I can tolerate it							X			
		5. I dislike it										
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers	
14C	How would you rank the petrol engine feature?	Importance Level Not Extremely 1 2 3 4 5 6 7 8 9 10	4		5	I	9		3		7	I
				I						R		
				4		5		9		3		7

No.	Question	Answers (select with a X one choice only)	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation
14A	If the vehicle has petrol engine	1. I like it	X				X					
		2. I expect it										
		3. I'm neutral		A				A	X			
		4. I can tolerate it			X							
		5. I dislike it									X	
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers	
14B	If the vehicle doesn't have petrol engine	1. I like it										
		2. I expect it										
		3. I'm neutral	X		X		X		X		X	
		4. I can tolerate it										
		5. I dislike it										
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers	
14C	How would you rank the petrol engine feature?	Importance Level Not Extremely 1 2 3 4 5 6 7 8 9 10	10		3		7		5	I	6	
						I						R
				10		3		7		5		6

No.	Question	Answers (select with a X one choice only)	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers
14A	If the vehicle has petrol engine	1. I like it											
		2. I expect it											
		3. I'm neutral	X		X				X		X		
		4. I can tolerate it											
		5. I dislike it					X						
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers		Answers
14B	If the vehicle doesn't have petrol engine	1. I like it											
		2. I expect it					X						
		3. I'm neutral	X		X				X		X		
		4. I can tolerate it											
		5. I dislike it											
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers		Answers
14C	How would you rank the petrol engine feature?	Importance Level Not Extremely 1 2 3 4 5 6 7 8 9 10	4	I	6	I	3		4	I	8	I	
								R					
				4		6		3		4		8	

No.	Question	Answers (select with a X one choice only)	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation
15A	If the vehicle has electrical motor engine	1. I like it		I		I	X	A		R		R		R		R		I		R		I	X	A		R		I		I	X	O	X	A		I		R		I		R
		2. I expect it															X																									
		3. I'm neutral	X		X																X						X		X						X				X			
		4. I can tolerate it																																								
		5. I dislike it							X		X		X		X				X						X												X				X	
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers	
15B	If the vehicle doesn't have electrical motor engine	1. I like it							X						X				X																						X	
		2. I expect it											X				X								X												X					
		3. I'm neutral	X		X		X				X										X		X				X		X				X		X				X			
		4. I can tolerate it																																								
		5. I dislike it																													X											
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers	
15C	How would you rank the electrical motor engine feature?	Importance Level Not ← → Extremely 1 2 3 4 5 6 7 8 9 10	5				4		4		5		3		4		7		3		7		10		1		5		2		4		4		5		1		4		1	
				5				4		4		5		3		4		7		3		7		10		1		5		2		4		4		5		1		4		1

No.	Question	Answers (select with a X one choice only)	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation
16A	If the vehicle has the capability to be air deployed	1. I like it		I		I	X	A		R	X	A	X	A	X	A	X	O	X	O	X	O		M	X	A	X	A	X	A	X	A		M		I	X	A	X	A	X	A
		2. I expect it	X		X																		X										X		X							
		3. I'm neutral																																								
		4. I can tolerate it																																								
		5. I dislike it							X																																	
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers	
16B	If the vehicle doesn't have the capability to be air deployed	1. I like it																																								
		2. I expect it																							X																	
		3. I'm neutral					X		X		X		X														X				X						X				X	
		4. I can tolerate it	X		X										X														X						X				X			
		5. I dislike it															X		X		X		X										X									
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers	
16C	How would you rank the capability to be air deployed feature?	Importance Level Not ← → Extremely 1 2 3 4 5 6 7 8 9 10	8		7		5		5		8		6		8		10		8		8		10		9		8		7		4		7		8		5		7		8	
				8		7		5		5		8		6		8		10		8		8		10		9		8		7		4		7		8		5		7		8

No.	Question	Answers (select with a X one choice only)	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation
17A	If the vehicle has the capability to be fitted with tracks	1. I like it		I	X	A	X	O		R	X	A		I		I	X	A	X	O	X	A		I		I		I	X	O		M		I		I		I	X	A		R
		2. I expect it																					X								X						X					
		3. I'm neutral	X										X		X										X		X						X									
		4. I can tolerate it																																	X							
		5. I dislike it							X																																X	
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers	
17B	If the vehicle doesn't have the capability to be fitted with tracks	1. I like it																																							X	
		2. I expect it																																	X							
		3. I'm neutral	X								X				X										X		X						X						X			
		4. I can tolerate it			X				X				X				X				X		X														X					
		5. I dislike it					X												X										X		X											
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers	
17C	How would you rank the capability to be fitted with tracks feature?	Importance Level Not ← → Extremely 1 2 3 4 5 6 7 8 9 10	3		6		10		4		7		4		4		7		1		5		10		3		7		3		7		6		2		7		8		1	
				3		6		10		4		7		4		4		7		1		5		10		3		7		3		7		6		2		7		8		1

No.	Question	Answers (select with a X one choice only)	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation	Answers	Evaluation
18A	If the vehicle has modular structure design	1. I like it	X	A		I	X	A		R	X	A	X	A		I	X	O	X	O	X	A		M		I		I		I		I		I		I	X	A	X	A		R
		2. I expect it			X																		X												X							
		3. I'm neutral													X										X		X		X		X		X									
		4. I can tolerate it																																								
		5. I dislike it							X																																X	
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers	
18B	If the vehicle doesn't have modular structure design	1. I like it							X																																X	
		2. I expect it					X																																			
		3. I'm neutral			X						X				X										X		X		X		X		X				X		X			
		4. I can tolerate it	X										X								X														X							
		5. I dislike it															X		X				X																			
No.	Question	Answers (select with a X one choice only)	Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers		Answers	
18C	How would you rank the modular structure design feature?	Importance Level Not ← → Extremely 1 2 3 4 5 6 7 8 9 10	8		6		6		3		7		7		4		9		8		5		10		5		5		3		8		5		7		4		5		1	
				8		6		6		3		7		7		4		9		8		5		10		5		5		3		8		5		7		4		5		1

Appendix C Design Drivers

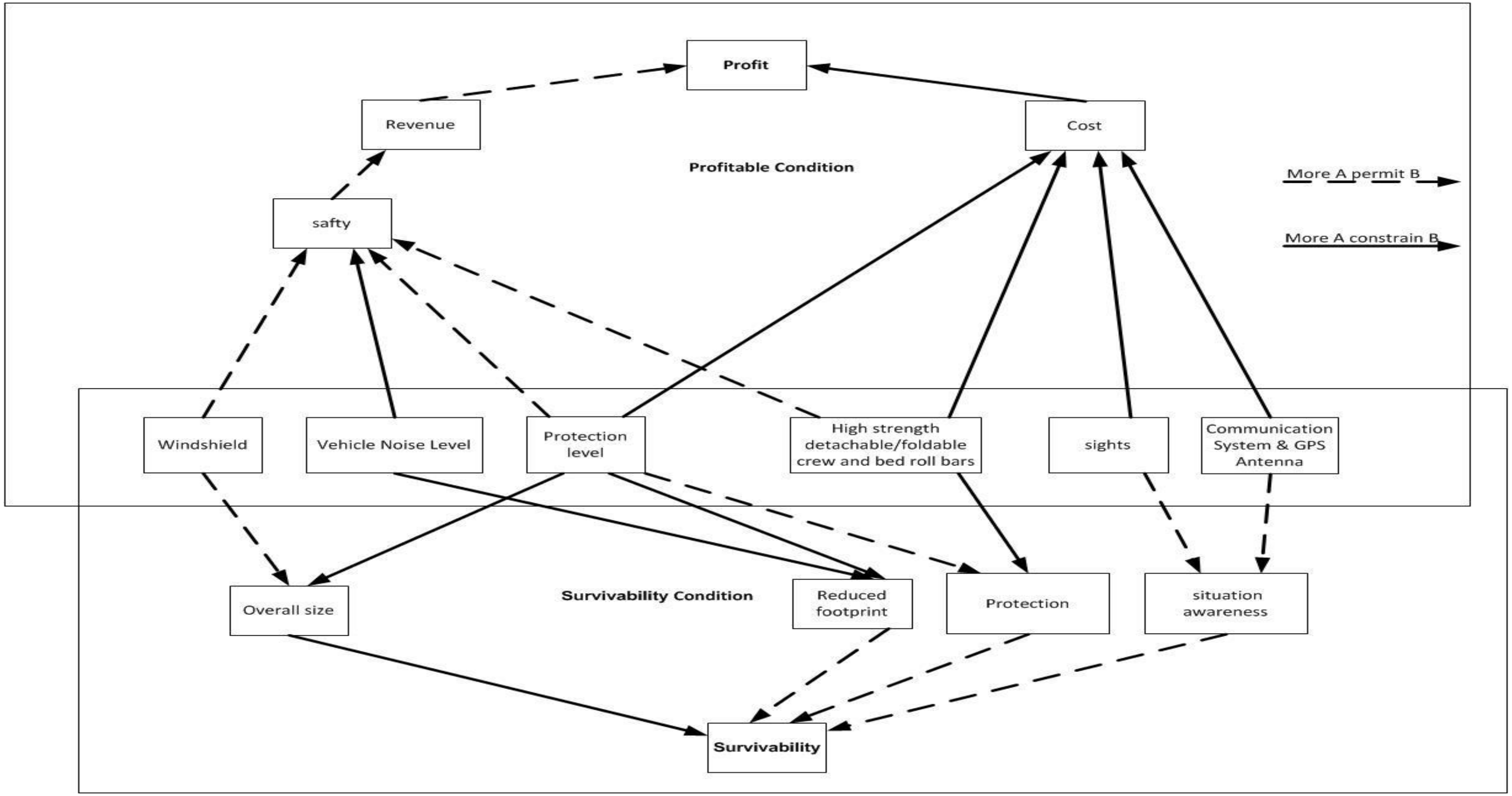


Figure C-1 Design Drivers-survivability

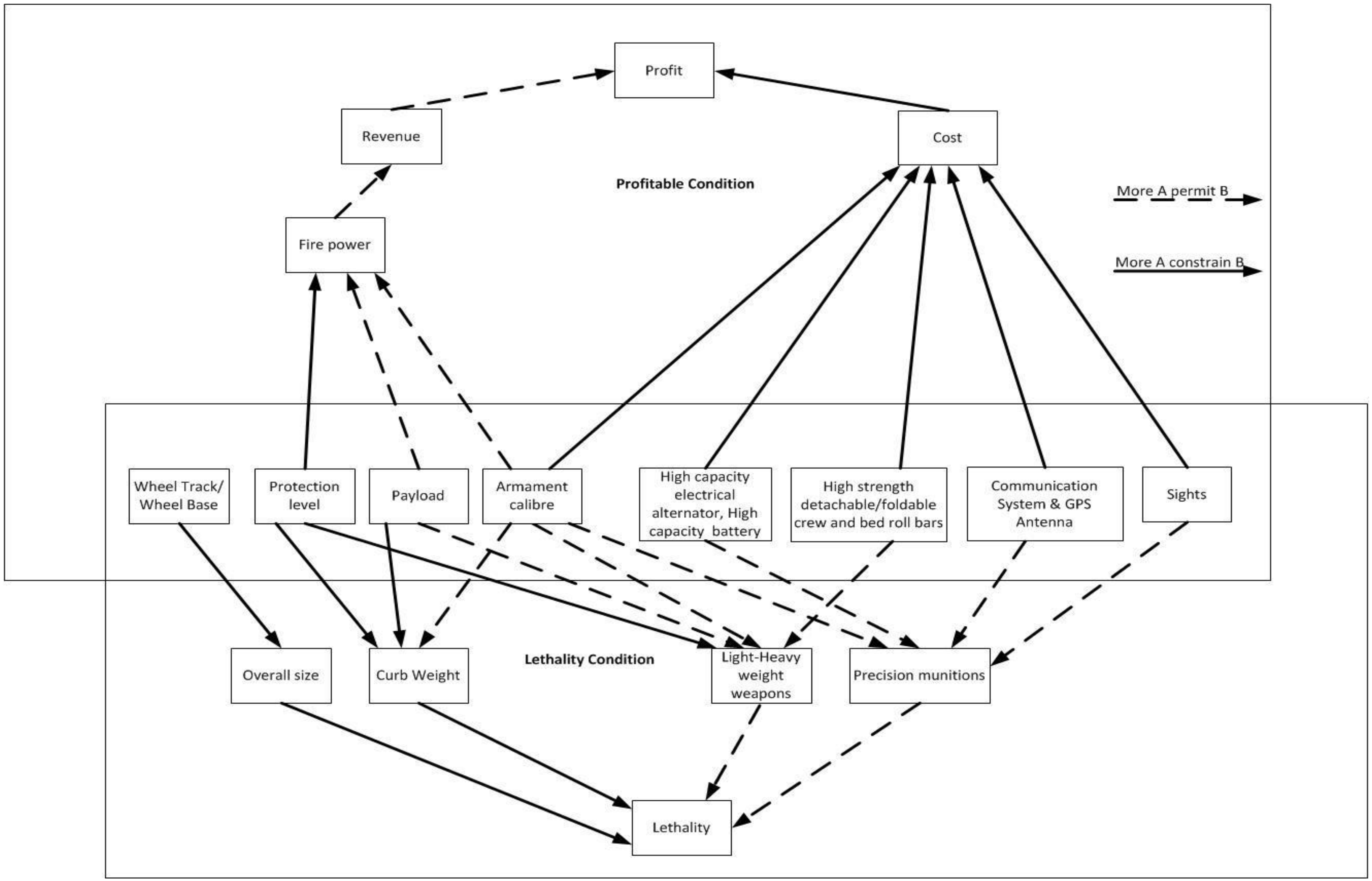


Figure C-2 Design Drivers-lethality

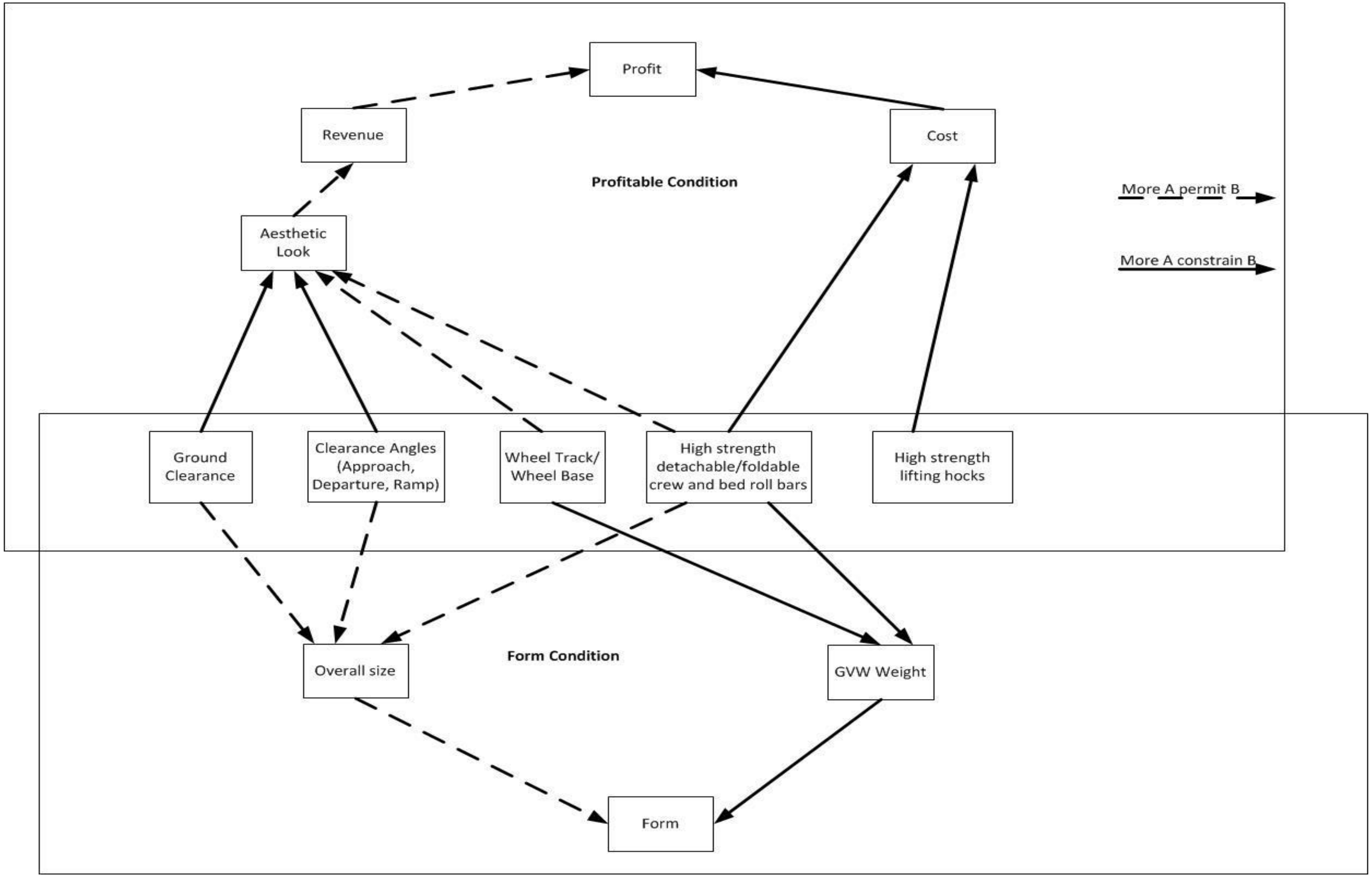


Figure C-3 Design Drivers-form

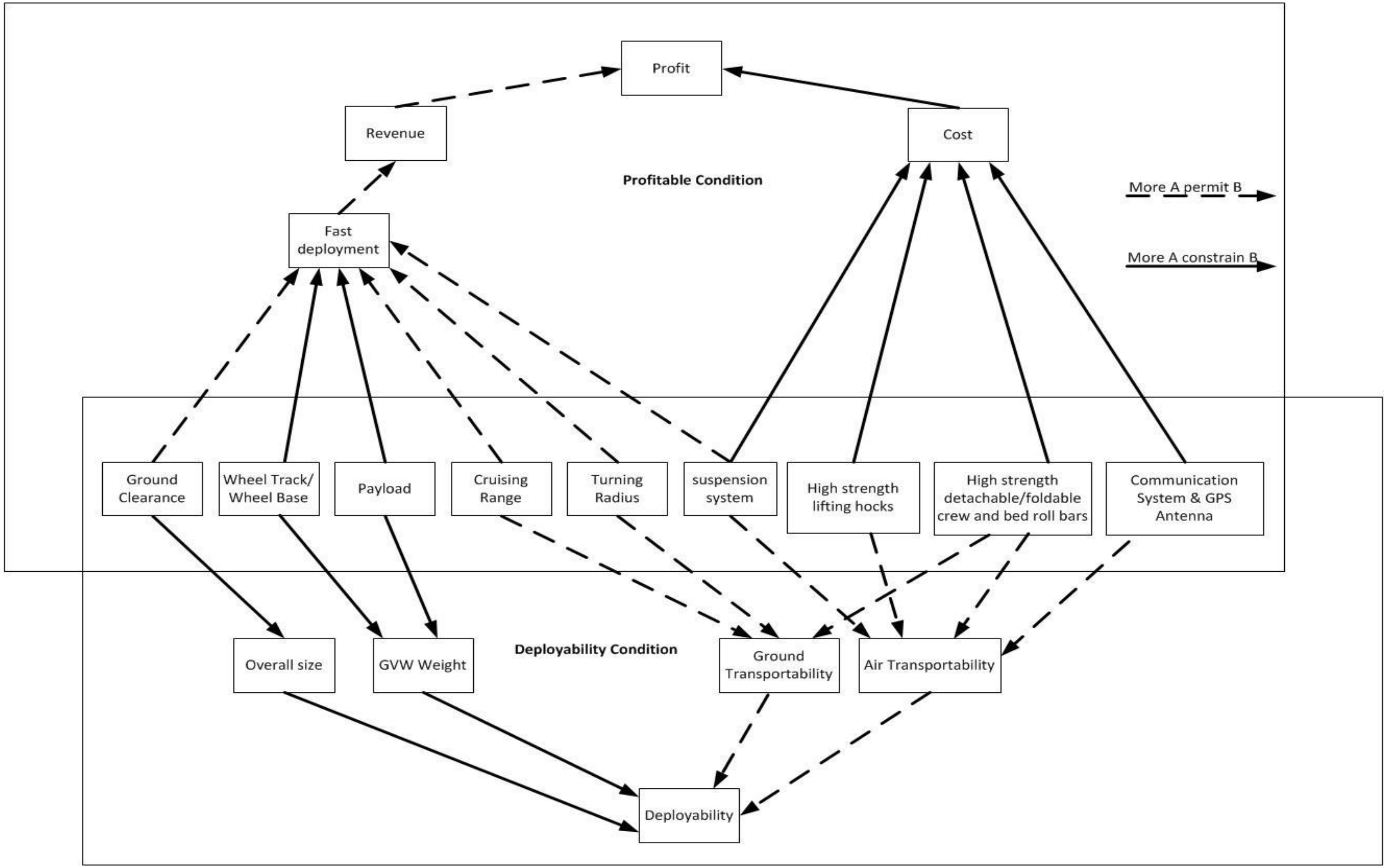


Figure C-4 Design Drivers-deployability

Appendix D Complete Hierarchical Function Structure

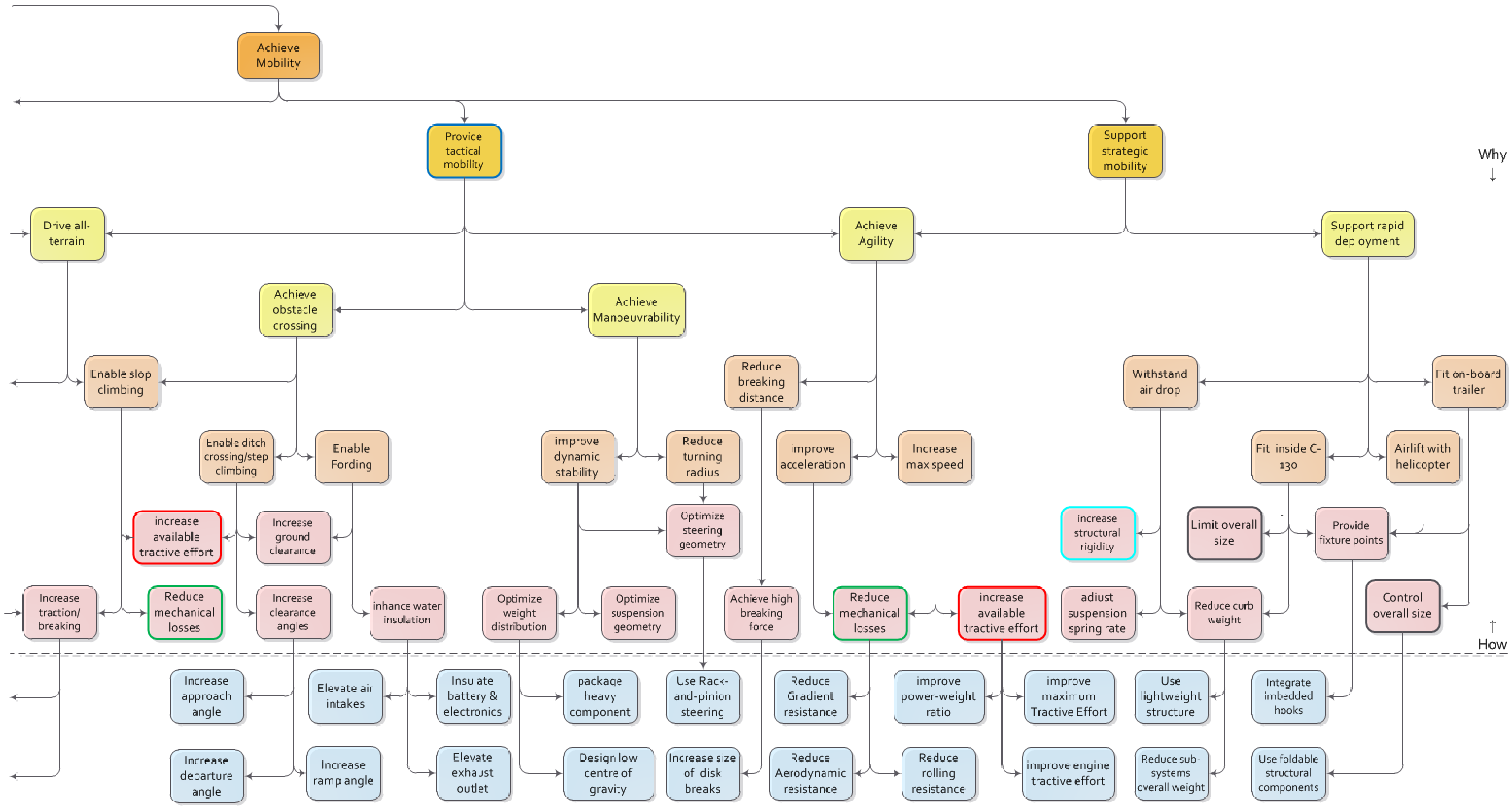
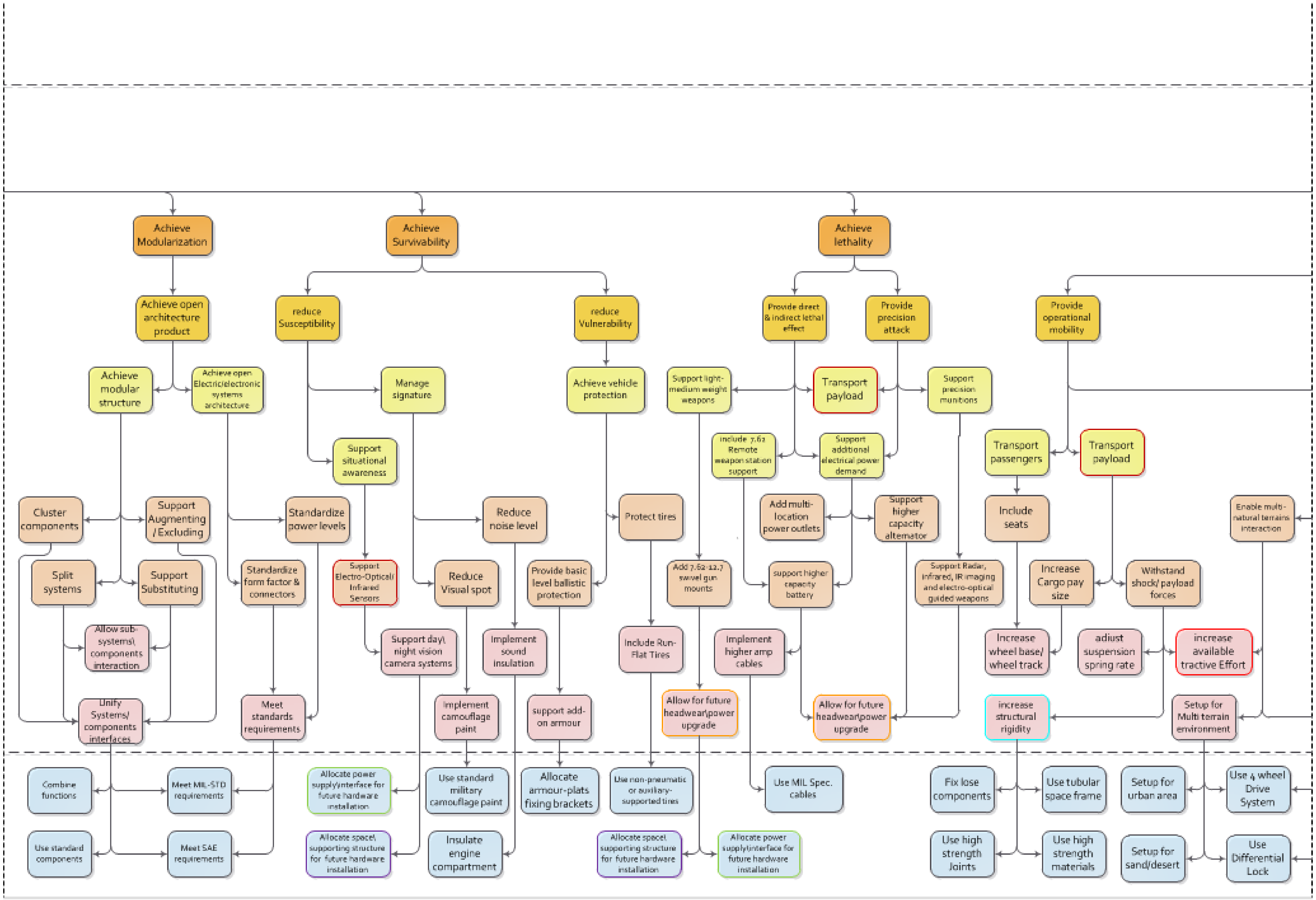
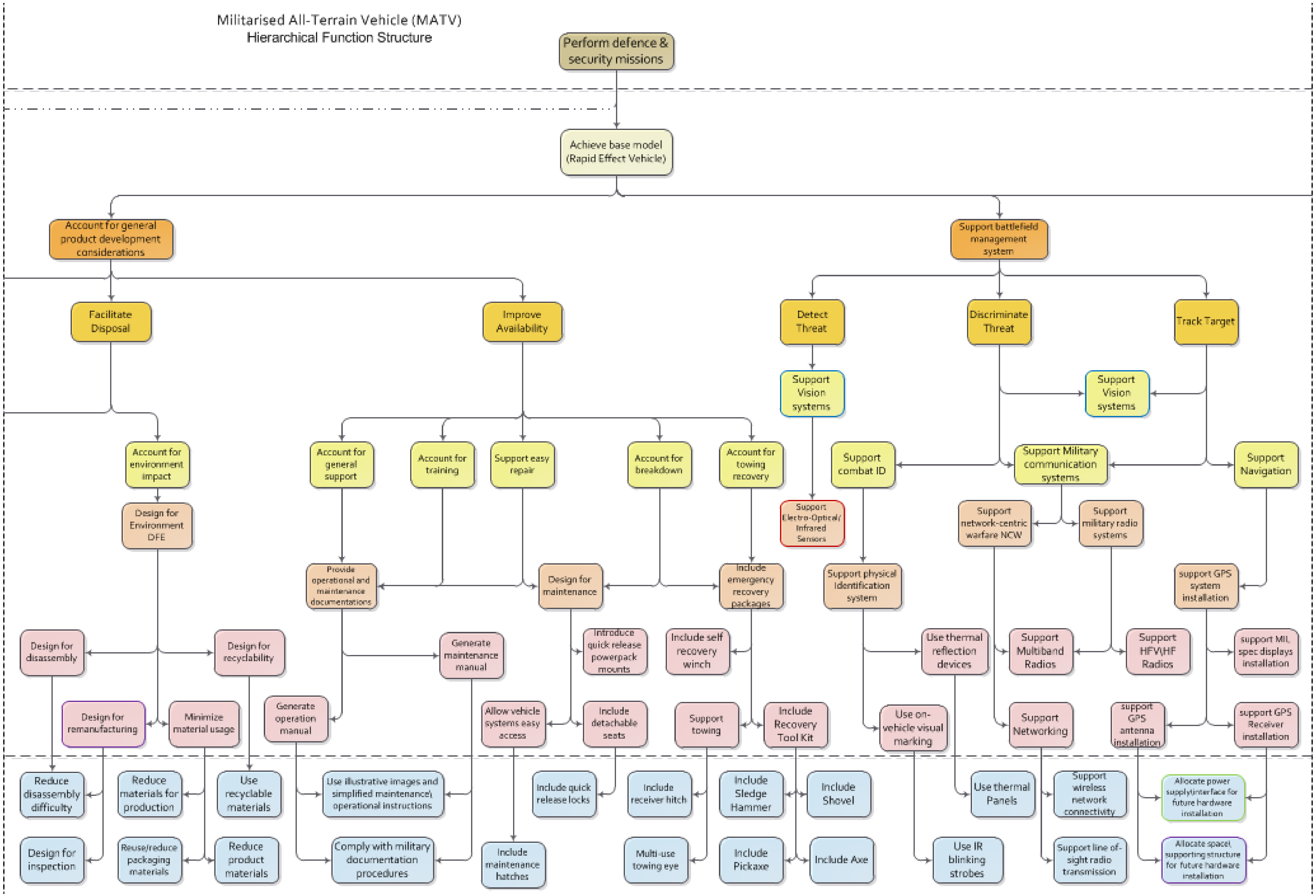
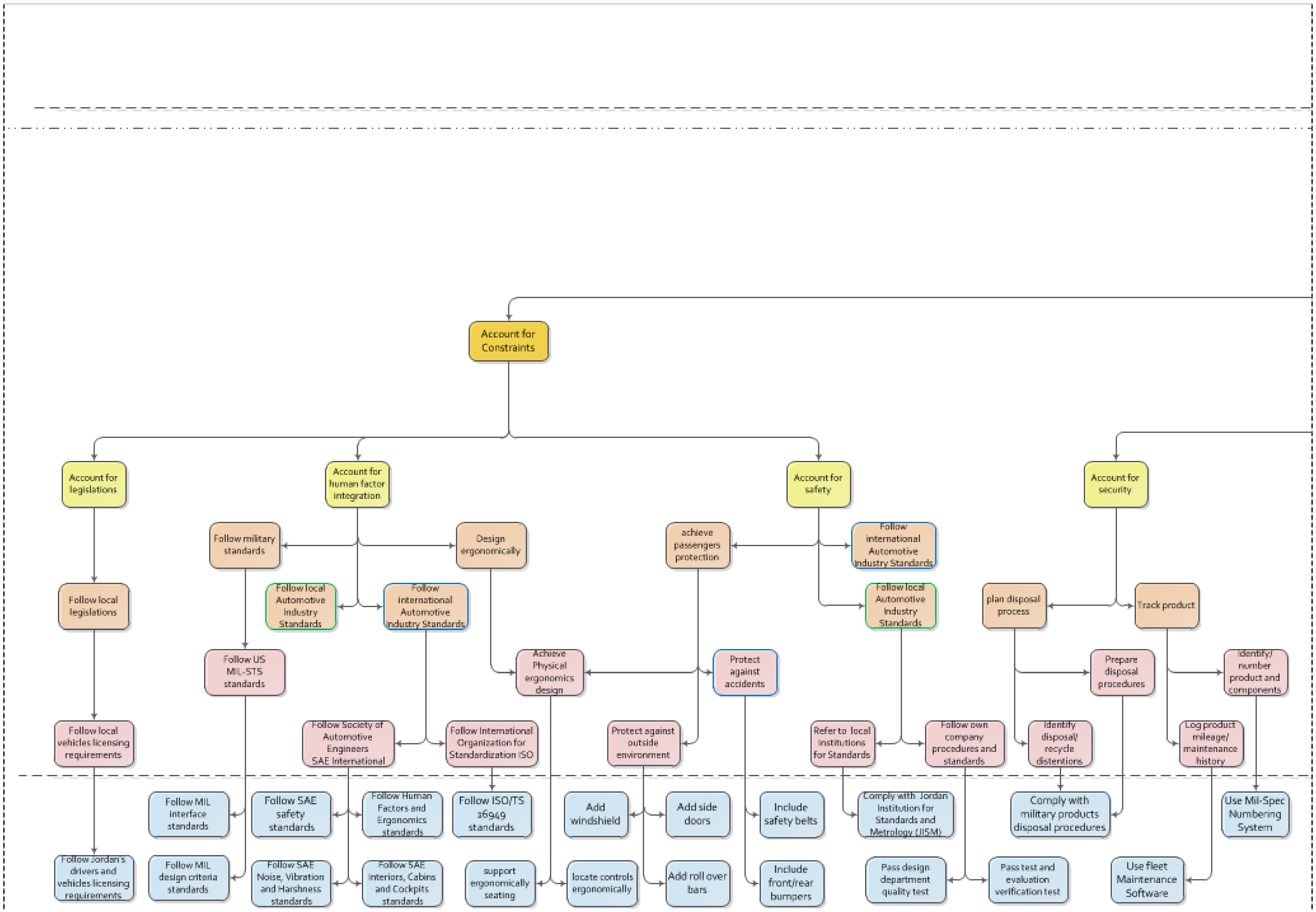


Figure D-1 Complete hierarchical function structure


Achieve Modularization
Achieve Survivability
Achieve lethality
Achieve open architecture product
reduce Susceptibility
reduce Vulnerability
Provide direct & indirect lethal effect
Provide precision attack
Provide operational mobility
Achieve modular structure
Achieve open Electric/electronic systems architecture
Manage signature
Achieve vehicle protection
Support light-medium weight weapons
Transport payload
Support precision munitions
Support situational awareness
include 7.62 Remote weapon station support
Support additional electrical power demand
Transport passengers
Transport payload
Cluster components
Support Augmenting / Excluding
Standardize power levels
Reduce noise level
Protect tires
Add multi-location power outlets
Support higher capacity alternator
Include seats
Enable multi-natural terrains interaction
Split systems
Support Substituting
Standardize form factor & connectors
Support Electro-Optical/ Infrared Sensors
Reduce Visual spot
Provide basic level ballistic protection
Add 7.62-12.7 swivel gun mounts
support higher capacity battery
Support Radar, Infrared, IR imaging and electro-optical guided weapons
Increase Cargo pay size
Withstand shock/ payload forces
Allow sub-systems\ components interaction
Support day\ night vision camera systems
Implement sound insulation
Include Run-Flat Tires
Implement higher amp cables
Increase wheel base/ wheel track
adjust suspension spring rate
increase available tractive Effort
Unify Systems/ components interfaces
Meet standards requirements
Implement camouflage paint
support add-on armour
Allow for future headwear\power upgrade
Allow for future headwear\power upgrade
increase structural rigidity
Setup for Multi terrain environment
Combine functions
Meet MIL-STD requirements
Allocate power supply\interface for future hardware installation
Use standard military camouflage paint
Allocate armour-plats fixing brackets
Use non-pneumatic or auxiliary-supported tires
Use MIL Spec. cables
Fix lose components
Use tubular space frame
Setup for urban area
Use 4 wheel Drive System
Use standard components
Meet SAE requirements
Allocate space\ supporting structure for future hardware installation
Insulate engine compartment
Allocate space\ supporting structure for future hardware installation
Allocate power supply\interface for future hardware installation
Use high strength Joints
Use high strength materials
Setup for sand/desert
Use Differential Lock


Militarised All-Terrain Vehicle (MATV)
Hierarchical Function Structure
Perform defence & security missions
Achieve base model (Rapid Effect Vehicle)
Account for general product development considerations
Support battlefield management system
Facilitate Disposal
Improve Availability
Detect Threat
Discriminate Threat
Track Target
Support Vision systems
Support Vision systems
Account for environment impact
Design for Environment DFE
Account for general support
Account for training
Support easy repair
Account for breakdown
Account for towing recovery
Support combat ID
Support Military communication systems
Support Navigation
Support Electro-Optical/ Infrared Sensors
Support network-centric warfare NCW
Support military radio systems
Provide operational and maintenance documentations
Design for maintenance
Include emergency recovery packages
Support physical identification system
support GPS system installation
Design for disassembly
Design for recyclability
Generate maintenance manual
Introduce quick release powerpack mounts
Include self recovery winch
Use thermal reflection devices
Support Multiband Radios
Support HFV\HF Radios
support MIL spec displays installation
Design for remanufacturing
Minimize material usage
Generate operation manual
Allow vehicle systems easy access
Include detachable seats
Support towing
Include Recovery Tool Kit
Use on-vehicle visual marking
Support Networking
support GPS antenna installation
support GPS Receiver installation
Reduce disassembly difficulty
Reduce materials for production
Use recyclable materials
Use illustrative images and simplified maintenance\ operational instructions
Include quick release locks
Include receiver hitch
Include Sledge Hammer
Include Shovel
Use thermal Panels
Support wireless network connectivity
Allocate power supply\interface for future hardware installation
Design for inspection
Reuse/reduce packaging materials
Reduce product materials
Comply with military documentation procedures
Include maintenance hatches
Multi-use towing eye
Include Pickaxe
Include Axe
Use IR blinking strobes
Support line of-sight radio transmission
Allocate space\ supporting structure for future hardware installation



Account for Constraints
Account for legislations
Account for human factor integration
Account for safety
Account for security
Follow military standards
Design ergonomically
achieve passengers protection
Follow international Automotive Industry Standards
Follow local legislations
Follow local Automotive Industry Standards
Follow international Automotive Industry Standards
Follow local Automotive Industry Standards
plan disposal process
Track product
Follow US MIL-STS standards
Achieve Physical ergonomics design
Protect against accidents
Prepare disposal procedures
Identify/ number product and components
Follow local vehicles licensing requirements
Follow Society of Automotive Engineers SAE International
Follow International Organization for Standardization ISO
Protect against outside environment
Refer to local Institutions for Standards
Follow own company procedures and standards
Identify disposal/ recycle distentions
Log product mileage/ maintenance history
Follow MIL interface standards
Follow SAE safety standards
Follow Human Factors and Ergonomics standards
Follow ISO/TS 16949 standards
Add windshield
Add side doors
Include safety belts
Comply with Jordan Institution for Standards and Metrology (JISM)
Comply with military products disposal procedures
Use Mil-Spec Numbering System
Follow Jordan's drivers and vehicles licensing requirements
Follow MIL design criteria standards
Follow SAE Noise, Vibration and Harshness standards
Follow SAE Interiors, Cabins and Cockpits standards
support ergonomically seating
locate controls ergonomically
Add roll over bars
Include front/rear bumpers
Pass design department quality test
Pass test and evaluation verification test
Use fleet Maintenance Software

Appendix E Product Architecture-Clustering Categories

E.1 Clustering

Table E-1 Electric\Electronic systems category

No.	Basic function description
1	Insulate battery & electronics
2	Allocate power supply\interface for future hardware installation
3	Use MIL Spec. cables

Table E-2 Powertrain category

No.	Basic function description
1	Improve maximum tractive effort
2	Improve engine tractive effort
3	Improve power-weight ratio
4	Reduce rolling resistance
5	Use 4 wheels drive System
6	Use differential Lock
7	Setup for sand/desert
8	Use non-pneumatic or auxiliary-supported tires

Table E-3 Steering system category

No.	Basic function description
1	Use rack-and-pinion steering

Table E-4 Break system category

No.	Basic function description
1	Increase size of disk brakes

Table E-5 Protection category

No.	Basic function description
1	Use standard military camouflage paint
2	Allocate armour-plats fixing brackets
3	Use thermal Panels
4	Use IR blinking strobes
5	Include safety belts
6	Add windshield

Table E-6 Communication system category

No.	Basic function description
1	Support wireless network connectivity
2	Support line of-sight radio transmission

Table E-7 Accessories category

No.	Basic function description
1	Include Shovel
2	Include Axe
3	Include Sledge Hammer
4	Include Pickaxe
5	Include receiver hitch
6	Multi-use towing eye
7	Include quick release locks

Table E-8 Documentation and procedures category

No.	Basic function description
1	Meet MIL-STD requirements
2	Meet society of automotive engineers (SAE) requirements
3	Combine functions

No.	Basic function description
4	Design for inspection
5	Reduce disassembly difficulty
6	Use Mil-Spec Numbering System
7	Use fleet Maintenance Software
8	Comply with military products disposal procedures
9	Pass test and evaluation verification test
10	Comply with Jordan Institution for Standards and Metrology (JISM)
11	Pass design department quality test
12	Follow ISO/TS 16949 standards
13	Follow Human Factors and Ergonomics standards
14	Follow SAE Interiors, Cabins and Cockpits standards
15	Follow SAE safety standards
16	Follow SAE Noise, Vibration and Harshness standards
17	Follow MIL interface standards
18	Follow MIL design criteria standards
19	Follow Jordan's drivers and vehicles licensing requirements
20	Use illustrative images and simplified maintenance\operational instructions
21	Comply with military documentation procedures

E.2 Rough 3D geometric layout

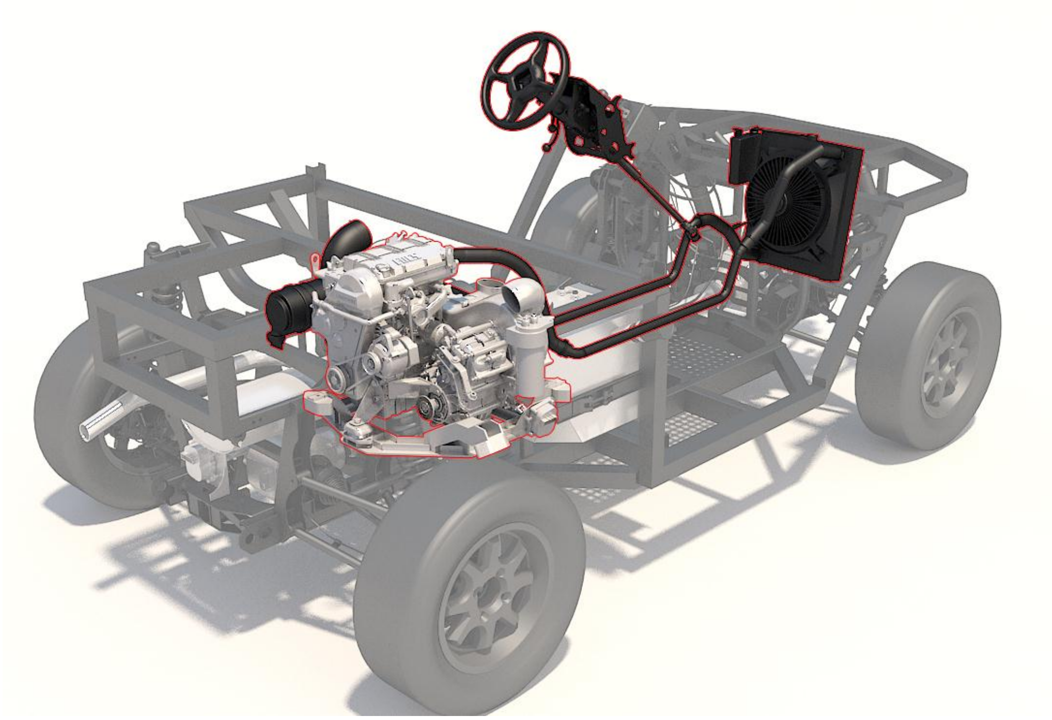


Figure E-1 Steering and cooling system

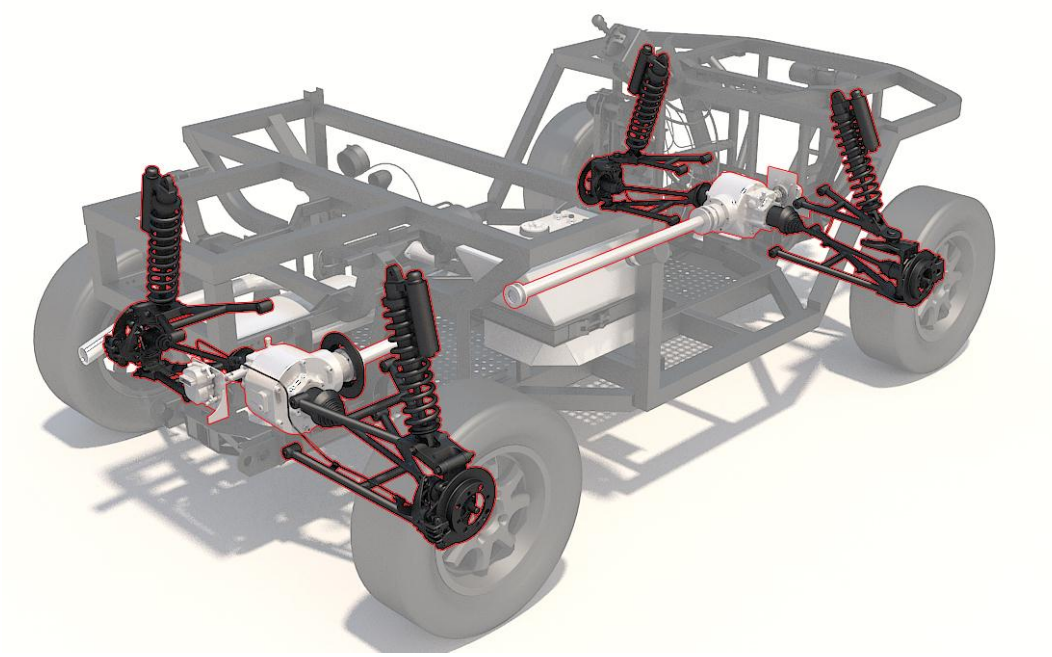


Figure E-2 Suspension system

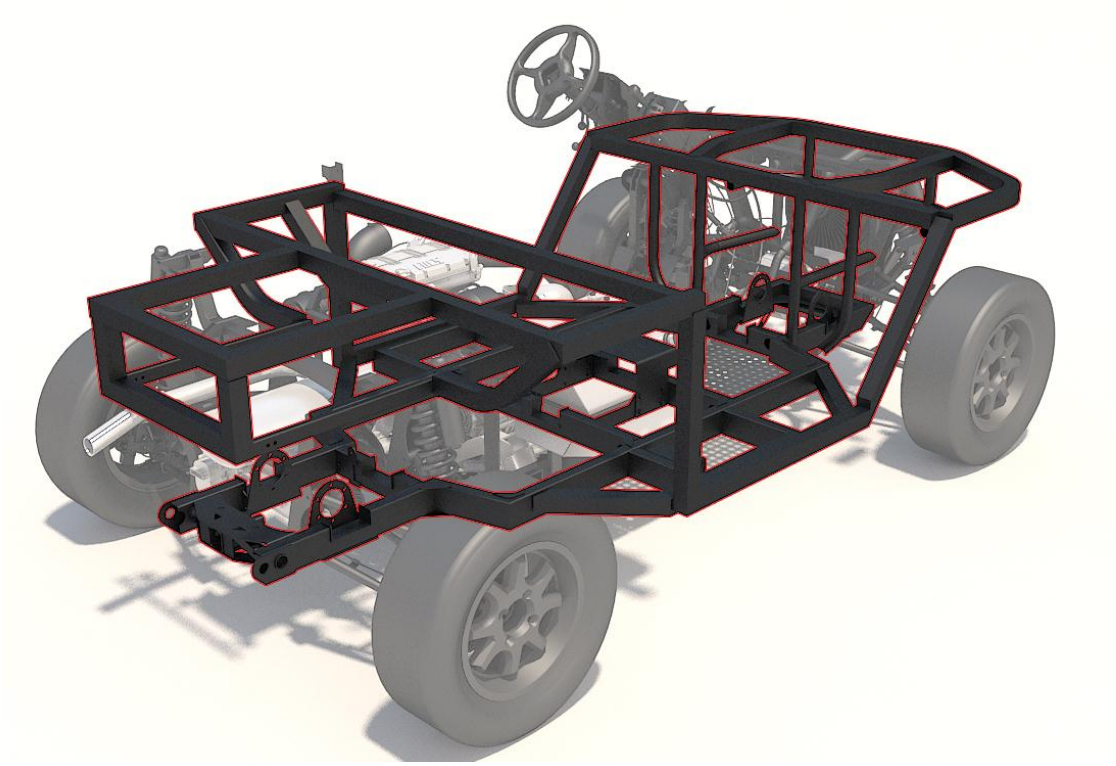


Figure E-3 Structure

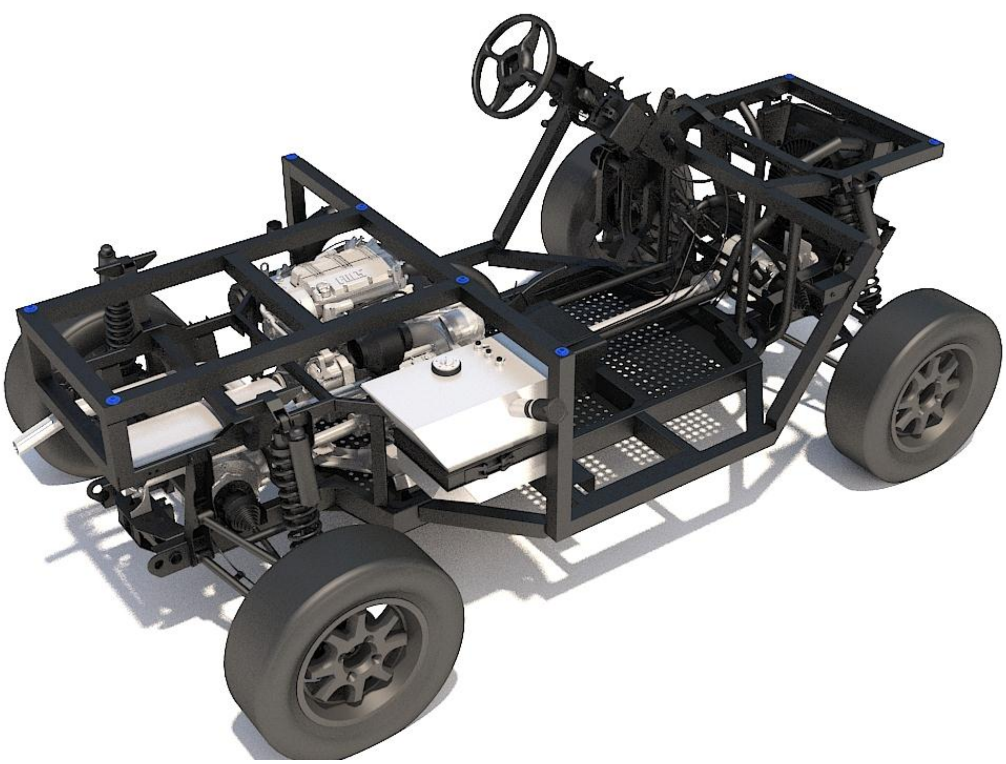


Figure E-4 MATV layout without roll cage

Figure E-5 MATV layabout with roll cage

Appendix F First Generation KADDB ATV Specifications

Specifications

Maximum Speed	60km/h
Gradability	60%
Approach Angel	56°
Departure angel	60°
Turning Radius	8.3 m
Engine	1028cc 20.0KW/ 27.2HP, Liquid-cooled with 3 in line cylinders
Transmission	Continuously variable transmission (belt-drive) 3 speeds (high, low and reverse), Selectable shaft 4x4 or 4x2, with front and rear differential control
Fuel Tank Capacity	42L
Suspension	4 Wheels Double Wishbone Independent Suspension
Steering	Rack and Pinion
Brakes	- Front: Dual piston hydraulic disc - Rear: Hydraulic Disc
Tires and Rims	R14-26x9
Chassis & Safety	Rigid tubular steel, with 2 passengers roll cage protection, tubular steel pumpers, and lifting rings
Seats and Harness	Suspended seats with head rest and 5 points seat belts
Length, Width, Height	335cm, 173cm, 200cm
Wheel Base	200cm
Ground Clearance	28cm
Payload	250kg
Dry Weight	850kg
Towing Load	750kg
Range (off-road and fully loaded)	320km
Electrical & Instruments	12V, 75Am battery with 65Am Alternator, Multi-Function Digital Meter, Standard Driving, Tail/Brake lights, and map light, and electrical winch
Optional	4passengers roll cage protection, Blackout / IR Lighting, Tire Balls® branded Flat Proof Tech

Figure F-1 First Generation KADDB ATV specifications